ZOÖLOGY

DESCRIPTIVE AND PRACTICAL

COLTON

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ZOÖLOGY

DESCRIPTIVE AND PRACTICAL

BY

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Part I

DESCRIPTIVE

D. C. HEATH & CO., PUBLISHERS

BOSTON NEW YORK CHICAGO

THE VOICE OF THE SEA

"The child holds a shell to his ear and hears the roaring of the sea. Do not yet tell him that the sound he hears is only the echo of the rushing of blood in his own head. In a higher sense the child is right. To him it speaks of the sea, its home. It brings the inland child a message from the vast ocean — the distant — the mysterious. It widens his narrow horizon; it takes him to the shore whose waters wash all other shores. He is no longer isolated, but put in touch with all the world. And this typifies the broad principle that one fact — considered in all its relations — involves the whole universe."

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PRINTED IN U. S. A.

PREFACE.

THE PLAN. — The general plan of the book is to introduce each of the larger groups of animals by the careful study of a typical representative. It is the aim to present a fairly complete picture of the *life* of this type, — its place of living; its manner of securing food; its enemies and its means of protection; its mode of locomotion; the processes of digestion, circulation, and respiration; its sense organs; its development; its relations to the plant world, to other animals, and to man. Following the study of the type is a general account of representative forms. The characteristics of the group are given in summarized form. Each chapter closes with a tabular classification of the group.

TIME FOR THE STUDY OF ZOÖLOGY. — Of the three seasons during which school is in session, winter is the least desirable for the study of animals. Many of the birds have migrated; most of the insects have been killed; those that remain alive are in close hiding and are hard to find, and still more so are their eggs, larvæ, or pupæ. A large number of animals are hibernating. Animal life is at low ebb. The choice of time, then, is practically limited to fall and spring. While there is an abundance of life in the spring and some forms can better be studied then, on the whole animal life is at its highest activity in the fall. Again, since spring is preferred for botany, the fall seems the best time for zoölogy.

THE ORDER OF STUDY. — The chief aim is to understand the lives of animals. To know them it is necessary to study them in relation to their surroundings. To do this to the best advantage they should be studied when at the hight of their activity. These points, then, must largely determine the order of study. For instance, if zoölogy is begun in the fall, one finds insects active and abundant. Many forms are laying their eggs to produce the generation of the following spring

They should be studied before the season of frosts. On the other hand, fishes can as well, or better, be studied later. Since the natural history point of view is prominent, the general principle regulating the order of study should be, "follow the season." The birds, too, should receive attention during the first part of the term, for many of them migrate early. It is not necessary, nor always desirable, to complete the study of one group before beginning another. Two lines of work can profitably be pursued on alternate days or weeks.

For fall work, the order here given has been found satisfactory. But circumstances call for considerable variation; it is not necessary to follow any given order with slavish fidelity. If the work begins in the spring, the teacher may prefer to begin with the crayfish, clam, fish, or frog.

There are some advantages in beginning with the lowest animals and studying them in the ascending order. This gives the clearest idea of the natural sequence of the animal kingdom.

Other things being equal, it would be better to study animals in their logical sequence, just as we prefer to learn historical facts in their chronological order. But there are very serious objections to this order. First, it involves the use of the microscope at the outset. This is impossible for many schools. Further, the use of the microscope is like a new language, which must be translated. Even if the student has a microscope and has mastered its technique, he still has difficulties. What he sees is very different from his previous observations. All our knowledge is knowledge of relation. Until the new is related to that already known, it means nothing. The very simplicity of the Protozoan makes it hard to understand.

If, however, the teacher decides upon this course, the work may begin with Chapter XVIII. By following the remaining chapters and then beginning with Chapter I, the ascending order will be followed with a few slight exceptions. But, as before stated, the teacher should not be tied down to any fixed order. Zoölogy is the study of animals. For most schools, the best time to study animals is when they can be most easily collected, for two reasons. First, it involves expense to keep them on hand to use at a later date. Second, and more important, the sooner they are studied after collection, the better. At this time some of the facts as to their source will appear, even if the students have not assisted in the collecting. The study of the home life and natural surroundings is of vital importance, if the student is to get

beyond morphology into the fields of natural history, ecology, and economic relations.

The Place of Nature Study. — Many teachers of natural history are accused, often very justly, of placing too high a value on the subject. The true teacher will try to see the real place of his subject in the course of study. Natural history cannot claim the highest place. Interesting as are the actions of animals, they cannot compare with the deeds of men. History is above natural history as man is above the other animals. But the student who has formed the habit of seeking the meanings of facts in natural history will carry this habit into the study of history. The study of natural history should come first, for children are interested in animals. The habits of observation and interpretation once formed will be carried through life and applied in every line of thought. To cultivate these habits should be the constant aim of the teacher. The study of animals especially lends itself to such training, because of the child's inherent interest in the subject, and because of the varied adaptations to their surroundings that animals everywhere exhibit.

The Interpretation of Nature. — The study of the relations of animals to their surroundings is a constant investigation of cause. The student must ask why an animal has a certain color, form, or habit. He must first learn to observe the facts that come within the range of his experience. Next, he must seek an explanation of these facts. He must become possessed by the idea that every fact has a meaning, and that it is worth while to think out this meaning. At first he must be helped; but he is to learn that he must rely mainly on himself for the solution of the problems of animal life.

Classification. — It is highly important that the student learn how to classify animals; that he commits to memory a system of classification is of doubtful value. To classify is simply to sort, or to arrange, things according to their likenesses. The child sorts his blocks; that is, he puts those of a kind together. Those of different kinds are separated. This is classification, — a grouping according to resemblances and differences. But the child cannot sort blocks unless he has them. Neither can the student classify animals unless he knows them. It is impossible to classify the unknown.

As the facts concerning the different kinds of animals become known, they must be sorted and arranged according to some system. The *basis* of *classifying animals* is *structure*. Of course the beginner cannot go deep into anatomy, but he must know some of the more important facts of structure or else his attempt at classification is comparatively useless. Since it is usually impracticable to study animals in systematic order, the student must learn to arrange his knowledge as he proceeds. This is not different from mental growth in other lines. Our experiences do not come to us classified. Just as an orderly merchant sorts his new goods, and arranges them on shelves with previously acquired articles of the same kinds, so the student must arrange in systematic order his ever increasing stock of knowledge.

At the close of the volume will be found the classification of the animal kingdom according to Parker and Haswell, whose arrangement is considered the most authoritative of recent works.

THE VALUE OF THE STUDY OF TYPES. — Real *knowledge* comes through experience. What one learns through another is *information*. The teacher must distinguish between first-hand knowledge and second-hand knowledge. Now the number of animals that any student can examine is small in comparison with the number in existence. The study of the animal kingdom is greatly simplified by the fact that, with all the variety of animal forms, there are actually but few different plans of structure. One important part of the teacher's work is to select the best types for careful study. On the foundation thus laid much information may be built. If one had never seen a Crustacean, he would get little from reading about Crustaceans. But, after studying a crayfish, a fairly clear idea of a lobster or a crab may be obtained by reading, for a foundation has been laid in sense perception.

The knowledge of a type may be compared to a peg in a wall; if it is driven in solid, it will hold many facts of information.

The types selected, their number, and the thoroughness with which they are studied will naturally vary with the locality, season, the age of the student, the time allotted to the study, and various other circumstances.

DEFINITIONS. — The student should be taught to make definitions. By comparing a number of related forms, as suggested in the practical work on insects, the student should see what characteristics they have

in common. Thus he is enabled to distinguish groups. Memorized definitions have comparatively little value. "A neat definition is a very attractive thing. It seems to offer the sum and substance of wisdom in portable form. But to understand it, to comprehend what it includes and what it excludes, the thoughts of the master must be gone over again in the mind of the disciple, — and then he no longer needs the definition." But definitions, however made, are often misleading. The fact is that nature has not sharply and distinctly separated animals into groups. There are usually no hard and fast lines between them. If we try to establish a dividing line, we almost always find it cutting across some intermediate forms. Since the groups of animals overlap, and gradually shade off one into another, it is better not to try to think of them as having definite boundary lines. We should rather consider each group as arranged about a type at the center.

Practical Work. — It has been thought best to place the practical work in the latter part of the book. But this work should, of course, precede the assignment of lessons in the descriptive text. Effort has been made to correlate the two parts so that they may be used together to good advantage. The author is well aware that in many schools the facilities for field and laboratory work are very limited. He has, therefore, thought best to err on the safe side and give rather full descriptions. But the teacher should see to it that the student himself solves as many as possible of the problems.

The teacher may find help in the "Suggestions to the Teacher of Zoölogy," which is issued in pamphlet form by the publishers of this book.

Economic Importance of Animals. — The common schools aim primarily at intellectual acquisition and training rather than at industrial application. Still, the economic side of the study of animals should be kept clearly in mind. The public has a right to demand that the knowledge gained in school shall have some practical value. The economic side, too, is one of the most interesting, and should receive attention for this reason, if for no other. This is a line of work in which collateral reading may be most profitably followed. There are many Reports of the Department of Agriculture which may be obtained free on application to the Department of Agriculture, Wash-

ington, D.C. These pamphlets may serve as the nucleus of a reference library. These reports, and as many other books as the school can afford, should be accessible to the student, and he should be encouraged to use them freely.

ACKNOWLEDGMENT. — The manuscript, entire or in part, has been critically read by Professors M. A. Bigelow, Teachers College, Columbia University; H. Garman, State College of Kentucky; F. R. Lillie, University of Chicago; T. H. Montgomery, University of Pennsylvania; M. M. Ricker, Burlington, Iowa; and J. M. Tyler, Amherst College. The manuscript has been corrected by Miss Chestine Gowdy, teacher of grammar, Illinois State Normal University.

The proofs have been read by Professors M. F. Arey, State Normal School, Cedar Falls, Iowa; A. C. Boyden, State Normal School, Bridgewater, Massachusetts; M. J. Elrod, University of Montana; J. W. Folsom, University of Illinois; H. Garman, State College of Kentucky; W. S. Jackman, University of Chicago; H. S. Jennings, University of Michigan; J. M. Johnson, Peter Cooper High School, New York; S. J. Hunter, University of Kansas; Louis Murbach, Detroit High School; Frank Smith, University of Illinois; H. B. Ward, University of Nebraska. To all of these the author extends his most sincere thanks. Their criticisms have weeded out many errors; but for those that remain they are in no way responsible.

In most cases the sources of the cuts are indicated in the captions. About forty of the cuts are original. The drawings of the clam were made by Mr. Frank J. George, now a teacher in the Philippines. Most of the other original drawings were made by Miss Esther Mohr.

NORMAL, ILLINOIS.

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ZOÖLOGY: DESCRIPTIVE AND PRACTICAL.

PART I. DESCRIPTIVE.

CHAPTER I.

BRANCH ARTHROPODA.

CLASS INSECTA.

Example. — The Grasshopper.

The Life of an Animal. — In order to understand the life of any animal, try to get answers to such questions as these: Where does it live? How is it adapted to its surroundings? What does it eat, and how does it get its food? What are its enemies, and how does it escape them? What is its chief mode of locomotion? What is it doing most of the time? What seems to be its main object in life? What changes does it undergo in its growth? Does it eat the same kind of food, breathe in the same way, move in the same way, or live in the same conditions during the different stages of its development? How does it affect plant life? What is its influence on other animals? Is it useful, either directly or indirectly, to man? Is it either directly or indirectly injurious to man?

Home Life of a Grasshopper. — As indicated in its name, we find this insect on plants. So well does its color har-

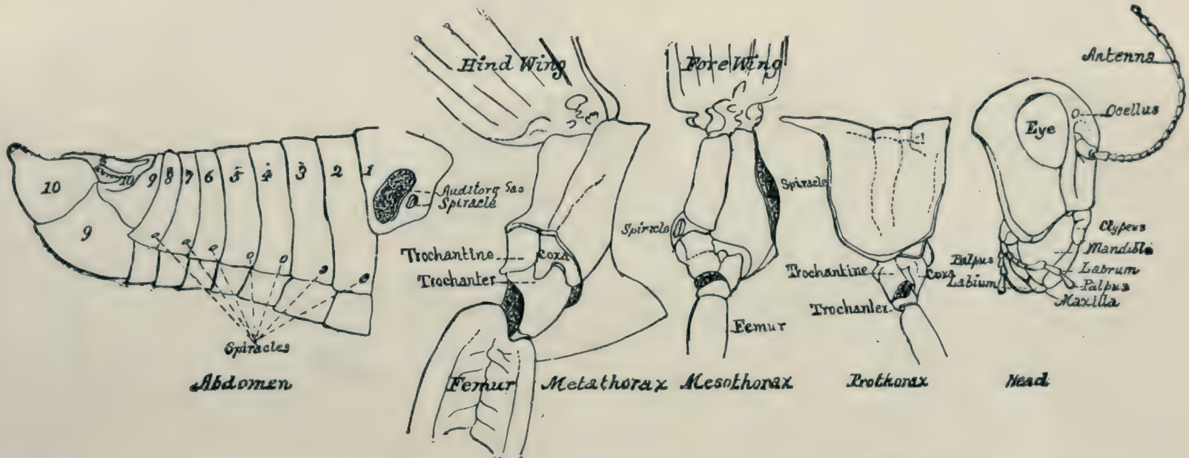


FIG. 1. EXTERNAL FEATURES OF A GRASSHOPPER, SIDE VIEW.

From Packard's *Zoölogy*.

monize with its surroundings that we often fail to see the grasshopper when it is right before our eyes. Even when we have frightened a grasshopper, and watch its jump or flight, on going to the place where we saw it alight we do not always readily discover it.

The plant on which the grasshopper rests serves both as food and as shelter; it is its home, so far as it can be said to have a home. Food usually being abundant, the grasshopper moves about but little, and leads a rather sluggish life.

Locomotion of the Grasshopper. — The grasshopper has three modes of locomotion, crawling, jumping, and flying. The wings and legs are moved by the strong, white, striated muscles, which are situated chiefly in the thorax.

Crawling. — This is accomplished mainly by the first and second pairs of legs, the hind pair making fewer movements in the ordinary slow crawl. The hooked claws enable the grasshopper to retain a firm hold while crawling.

Jumping. — The length and strength of the hind legs fit the grasshopper for powerful jumping. The spines on the hind border of the tibia keep it from slipping.

The Wings and Flying. — The anterior pair of wings serve mainly as covers for the hinder pair, and their comparative thickness and toughness fit them well for this use. The hinder pair of wings are much wider, being folded like a fan when not in use and wholly covered and protected by the anterior pair. The hinder pair are more delicate in their texture, but still are sufficiently strong for their work in flight, being stiffened by the hollow veins which radiate through them. The grasshopper is crawling through the grass or resting quietly on stems and leaves most of the time, and is flying only a small part of the

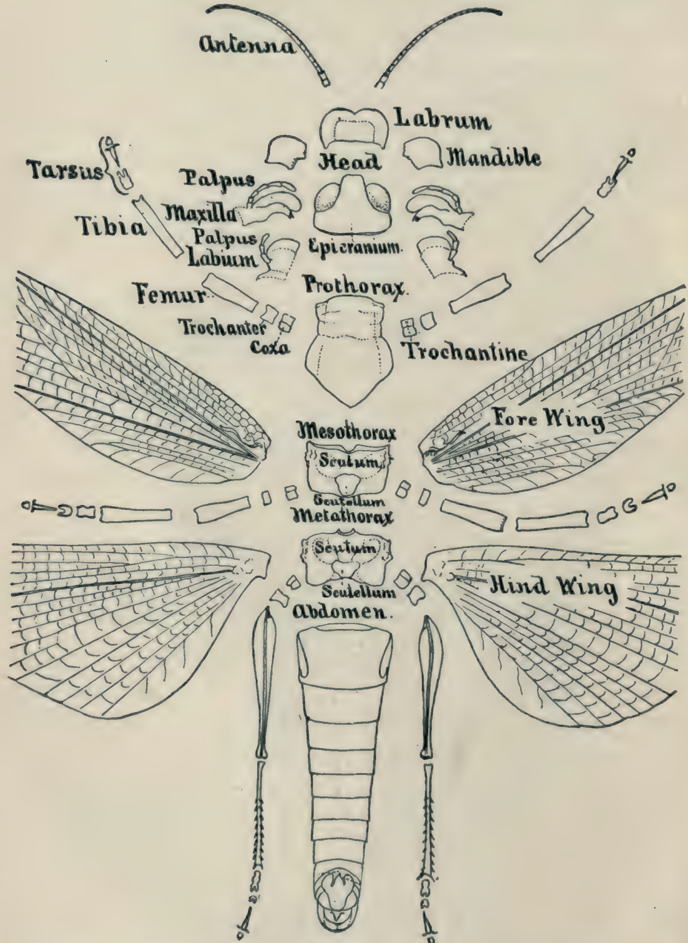


FIG. 2. EXTERNAL FEATURES OF A GRASSHOPPER, DORSAL VIEW.
From Packard's *Zoölogy*.

time. So we can see the fitness of having the flying wings folded compactly and placed close to the sides and guarded. The wings are kept from mutilation, and the whole insect is much less conspicuous than he would be with the wings outspread. Some grasshoppers fly high in the air and travel long distances.

Respiration in the Grasshopper. — The spiracles are shown in Fig. 1; two pairs of thoracic and eight pairs of abdominal openings. From these spiracles, tubes,

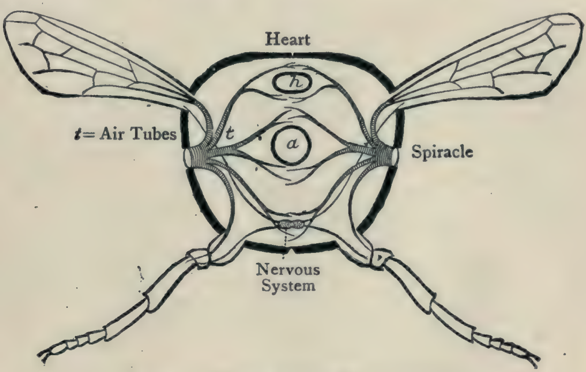


FIG. 3. CROSS SECTION OF INSECT.
a = Digestive Tube.

called tracheæ, run inward to a trachea extending lengthwise on each side of the body. There is also a pair of dorsal and a pair of ventral air tubes. There are, then, six air tubes running lengthwise, in communication with the outside air through the spiracles, and connected with each other by branches. From these main tubes branches extend which subdivide, finely permeating every part of the body, even, to a limited extent, the legs and the larger veins of the wings (see Figs. 3 and 4). In addition to the air tubes there are two rows of air sacs, which add to the

buoyancy during flight. The work of respiration depends on the abdomen, as the thorax is rigid. The abdomen is made smaller by the action of its muscles, and expands again when they relax. Expiration seems to be accomplished by active effort, and inspiration by elastic reaction, just the reverse of the breathing process in man.

Circulation in the Grasshopper. — The circulatory system of the grasshopper is not highly developed. The only distinct organ is the heart (see Figs. 3 and 4), extending along

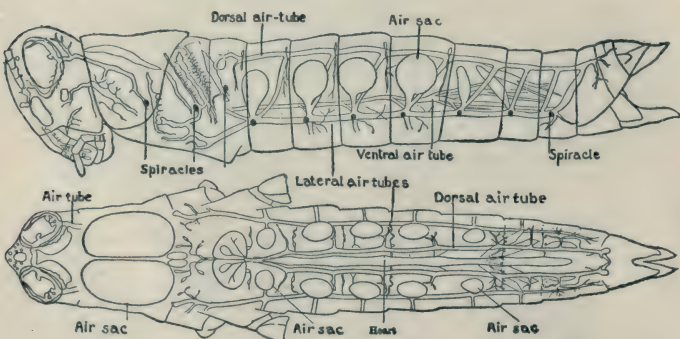


FIG. 4. AIR TUBES AND AIR SACS OF GRASSHOPPER.
From Hyatt's *Insecta*.

the dorsal part of the abdomen. It is in the form of a tube, closed behind and open at the anterior end. It has several compartments, with valves, which allow the blood to pass forward only. There are also openings with valves at the sides, so that blood enters when the tube widens, and when it contracts the blood is pumped forward. The blood is colorless, or slightly yellowish or greenish, and fills all the otherwise unoccupied spaces of the body, thus bathing all the tissues. The low development of the circulatory system is compensated for by the high develop-

ment of the respiratory system, which conveys air to all parts constantly. Thus the insect is enabled to exert its muscles powerfully and rapidly, and in general maintain the high degree of activity which is so characteristic of the group. As might be expected, the temperature of insects is high, compared with that of invertebrates in general, being several degrees above that of the surrounding air.

The Grasshopper's Food and Digestion. — Eating is a large factor in the life of the grasshopper. We see it on many kinds of plants, gnawing leaves and stems with its short, strong, laterally moving jaws. The narrow gullet extends upward to about the center of the head, then turns posteriorly and dilates into the crop, which runs lengthwise in the thorax. At about the beginning of the abdomen the crop narrows somewhat and becomes the stomach. Alongside the crop are the branched salivary glands, whose ducts run forward to empty into the mouth. At the place where the crop joins the stomach it is surrounded by a set of six or eight double-cone-shaped pouches extending parallel to the digestive tube itself. These bodies are the ceca. They are hollow and communicate with the cavity of the digestive tube by openings. The ceca secrete a liquid that aids in digestion; they increase the surface of the digestive tract and probably are largely concerned in the work of absorption. The stomach extends about half the length of the abdomen. Its posterior limit is marked by a large number of slender tubes, the urinary tubes, which enter the digestive tube at the juncture of the stomach and intestine. The last part of the intestine is somewhat dilated, forming the rectum, which, in turn, terminates in the anal opening at the upper part of the end of the abdomen.

Absorption in the Grasshopper. — The absorbed food materials from the digestive tube pass directly into the general blood of the body cavity, there being no special set of tubes as in man and vertebrates generally.

The Excretory System of the Grasshopper. — The urinary tubes (formerly called the malpighian tubes) extend into the blood of the body cavity and extract from it essentially the same materials as the kidneys of the higher animals do. As above stated, these tubes empty into the intestine.

The Nervous System of the Grasshopper. — The nervous system of the grasshopper is essentially like that of the crayfish (Fig. 49), consisting of a row of ganglions connected by a nerve cord lying along the floor of the body cavity. It really is composed of two rows of ganglions, each connected by its own chainlike cord; but usually the two corresponding ganglions unite, forming what seems a single ganglion. In the grasshopper, the nerve cord is plainly double throughout the head and thorax, while in the abdomen the cord appears single. There are ten ganglions, two belonging to the head, three in the thorax, and five in the abdomen. The first ganglion, often called the brain, is above, or rather in front, of the gullet. From this the two strands of the nerve cord pass to right and left of the gullet and again unite in the second, or infra-esophageal ganglion, forming the nerve ring ("nerve collar") found in arthropods and mollusks.

The Senses of the Grasshopper. — It is very evident that the grasshopper can see and hear, and it does not require extended experiment to show that it has also the sense of touch. The large compound eyes, composed of many facets, give a wide range of vision; but the sense of sight

is probably not very acute, especially at any considerable distance. The clear membrane on the first segment of the abdomen is the tympanum of the hearing organ. The antennæ are the chief organs of touch.

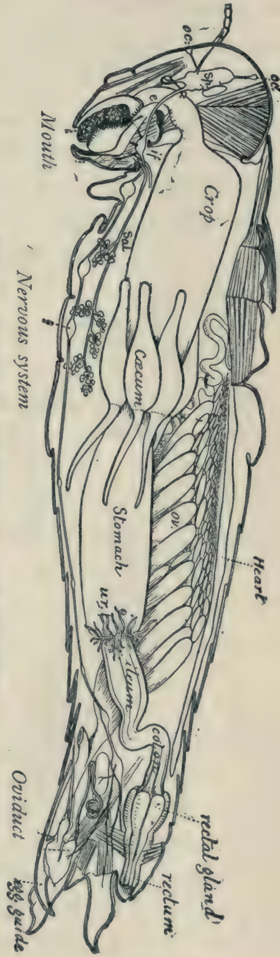


FIG. 5. INTERNAL ANATOMY OF A GRASSHOPPER.
oc, simple eyes; *sp*, brain; *e*, gullet; *if*, infra-esophageal ganglion; *sal*, salivary glands; *ov*, ovary (eggs); *ur*, kidneys.
From Hyatt's *Insecta*.

The Enemies of the Grasshopper. — Probably birds are the most formidable enemies of the grasshopper. The grasshopper usually becomes aware of the approach of an enemy through sight or hearing, and ordinarily escapes by flight or by jumping. They sometimes escape by simply dropping to the ground. The grasshopper is largely protected by his resemblance in color to that on which he habitually rests, some forms being usually on plants, while those that stay much of the time on the ground are more of the color of the soil. The position while on plants, parallel to the stem, makes them less conspicuous than they would be otherwise. Grasshoppers are often subject to injury by parasites, especially certain red mites which are often to be found under the

bases of the wings. They are often destroyed in large numbers by the growth of a parasitic fungus in their bodies. Every boy knows that when the grasshopper is captured he ejects from the mouth a dark liquid secreted by the crop. This is probably a means of defense.

Sounds made by Grasshoppers. — Sounds are produced by the males only. Some grasshoppers make the noise by rubbing the bases of the legs against the bases of the outer wings. Others, while flying, rub the under surface of the base of the outer wing over the upper surface of the base of the inner wing. The katydids and crickets make the sound, while at rest, by rubbing the wings against each other.

Colors of the Grasshopper. — Although the grasshopper is decidedly inconspicuous when at rest, on account of the protective resemblance in color, yet it is to be observed that in some species the inner wings are conspicuously colored, making the insect very noticeable during flight.

Development of the Grasshopper. — The ovaries occupy the upper part of the abdomen of the female. When full of ripe eggs they take a good share of the space in the abdomen. The oviducts extend down and back, opening between the sharp points at the end of the abdomen. These four sharp points together form the ovipositor. In laying the eggs the female presses the tips of the four points close together, which makes a strong and fairly good digging tool. This is thrust into the ground and the points are then separated, and by repeating this a hole is made, into which the eggs are introduced, passing out between the guides. The egg hatches out into a little grasshopper resembling the parent, but lacking wings.

After a time rudimentary wings appear. In all such cases as this, where the young are hatched in essentially the same form as the adult, the development is said to be direct.

Injury done by Grasshoppers. — Ancient history records plagues of locusts. (The name "locust" is the proper one for our common grasshopper.) And in modern times and near-by places there have been migrations of locusts in such numbers that they have darkened the sky, and, lighting everywhere, have devastated the land by eating almost

FIG. 6. GRASSHOPPER LAYING EGGS.
From Hyatt's *Insecta*.

every leaf and tender stalk of grass, crops, and trees in garden and field. The Rocky Mountain locust, migrating eastward, almost produced a famine in Kansas and Nebraska, and created terror beyond the limits of its actual ravages. But, fortunately, the young hatched in the lower states are not healthy, and die prematurely; hence the plague has not spread so extensively as it threatened to do.

Packard says that the Rocky Mountain locust, within a period of four years, inflicted a loss of $200,000,000 on the farmers of the West.

ORDER ORTHOPTERA.

The Orthoptera. — We have selected the grasshopper as the best available type of the class Insecta and also of the order Orthoptera. The word *Orthoptera* means straight-winged, probably in allusion to the mode of folding the hind wings. The first pair are thickened, serving as a cover for the second pair, which are folded when at rest. The mouth parts are fitted for biting. The development is direct.

FIG. 7. A WALKING STICK INSECT (*Diapheromera femorata*) ON TWIG. From Jordan and Kellogg's *Animal Life*.

Protective Resemblance. — The green grasshoppers, especially the katydid, are noteworthy for their resemblance to leaves, both in color and form. The walking stick (Fig. 7) so closely resembles a twig that it is seldom discovered by casual observers. These insects afford fine examples of the advantages of *protective resemblance.*

The green grasshoppers have a windowlike membrane on the tibia of each fore leg that is supposed to be an organ of hearing.

Classification of Orthoptera. — The families are: the short-horned grasshoppers (locusts), which we have studied;

the long-horned grasshoppers (usually green), including the katydid; the crickets; the cockroaches, including the "croton bug," so common about water pipes; the walking sticks; and the mantids.

ORDER ODONATA.

The Dragon Fly. — The dragon fly has a long, straight abdomen, and large eyes. The two pairs of net-veined wings are alike in texture and nearly of the same size. The wings are never folded, but when at rest are held out at right angles to the body, ready for instant use. There is a pair of strong jaws, which are nearly covered by the large under and upper lips. The dragon fly feeds on insects, which it catches on the wing, being one of the swiftest and strongest flying of insects. Dragon flies are most abundant in marshy places, where they may be seen flying over the water or perched on a leaf or stem above the water, on the alert for a passing mosquito or other small insect. The females lay the eggs in the water, and may often be seen hovering over the water with the tip of the abdomen dipping beneath the surface. An egg hatches into a form called a nymph, with strong jaws. It immediately begins to prey upon other insects and larvæ that it finds. When it has attained its growth it crawls up the stalk of some water plant, splits along the back, and the dragon fly emerges, leaving the empty skin still clinging to the stalk. The development is here also called direct. While living in water the larva breathes by taking water into the hind part of the digestive tube. Other dragon fly larvæ have rudimentary gills. Some of the smaller dragon flies, when at rest, place the wings close together, just above the body. These are called damsel flies. Dragon flies are

also called darning needles, devil's needles, snake feeders, snake doctors, spindles, and mosquito hawks. In the

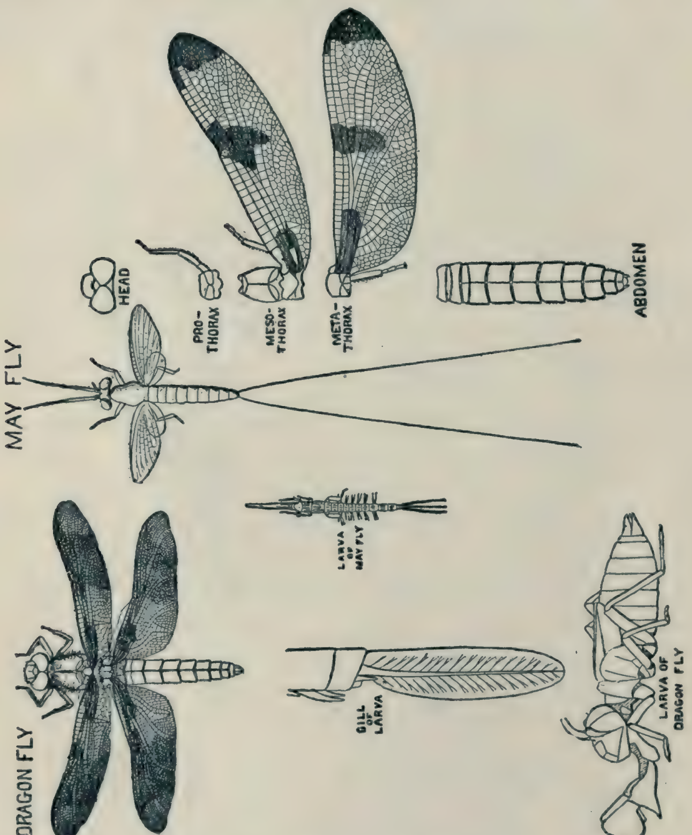


FIG. 8. DRAGON FLY AND MAY FLY.
From Hyatt's *Insecta*.

Northern states children and ignorant adults believe that these insects sew up people's ears, and in the South the

same classes think they bring dead snakes to life. It is easy to see how these stories arise. The long abdomen is supposed to hold a correspondingly long sting; while its mode of laying eggs (people not knowing what it is doing) gives it the name applied in the South. The name mosquito hawk is the most significant of its life and habits, for it has no sting, and is entirely harmless; but, on the other hand, it benefits man by destroying mosquitos and other insects.

Characteristics of Odonata. — The dragon flies represent the order Odonata. The chief characteristics of the order are: wings net-veined, the two pairs equal or nearly so; mouth parts fitted for biting; abdomen long and slender; development direct.

COMPARISON OF GRASSHOPPER AND DRAGON FLY.

GRASSHOPPER.		DRAGON FLY.
On land	Home	Over water
Plants	Food	Insects
Numerous	Enemies	Few
Strong — for jumping	Legs	Weak, merely for perching
Two pairs	Wings, number	Two pairs
First pair thick	Wings, texture of	Both pairs gauzy
Fold close to body First pair covering 2d	Wings, position, resting	Extended at right angle Not overlapping
Crawl through grass Elude observation	Position enables to	Dart after insects Exposure less dangerous

Adaptation to Mode of Life. — In addition to the above tabular representation of some of the most striking differences between the grasshopper and dragon fly, let us consider what characteristics each has that fit it for its particular mode and place of life, and which unfit it for

the mode of life of the other. Let us suppose that they trade places. It is not unfair to make this supposition, for they are not extremely unlike. Both have strong biting jaws, two pairs of strong wings, and a long abdomen.

In the first place, let us suppose that the dragon fly can subsist on vegetable food, and that it takes up its life as a grasshopper. It finds its long, projecting wings in the way. They not only hinder it as it attempts to crawl into narrow places, but are apt to be torn, for, though strong, their texture is delicate. So it will naturally turn the wings back alongside of the body, and for compactness will probably let one pair rest upon the other. It will further protect them if the outer wings become harder and tougher, but this change will be something of a sacrifice in flying power.

Again, when the wings are thus folded, the insect covers less area and is less conspicuous and therefore more likely to elude the eyes of birds or other enemies. Its legs, which are light and weak, having been used merely for support, need greater strength to enable it to crawl and jump. The eyes are not required to be so keen and naturally may become smaller, and as it leads a lazier life it becomes more corpulent and clumsy. To make up for the loss of flying power in the front wings, the hinder ones become wider; this necessitates their being folded when at rest in order that the narrower front wings may completely cover them.

Let us now consider how the grasshopper would fare in the endeavor to lead the life of the dragon fly. In the first place, the grasshopper lacks the flying power requisite to capture lively little insects on the wing It must have both pairs of wings developed for active use; and it can afford to do this, as it does not need to have the front pair

thickened, as in its situation covers are not needed. It should have wings constantly poised, ready to dart instantly after its prey. There is no objection to having the wings continually spread, as it lives in open spaces and does not have to crawl through grass and twigs; and the increased area due to the spread does not especially endanger it by making it more conspicuous, since it has comparatively few enemies. The body is too heavy, and it must "train down" until it can handle itself better. The legs are too heavy, especially the hind pair; and, as it uses them very little except to perch upon a leaf or twig, waiting for something to turn up, this matter takes care of itself, for any unused organ is likely to dwindle away.

It needs keener eyes, for it no longer feeds on plants which are sure to stay in place while it crawls upon them; it is another matter to discern small insects at some distance. So it develops better eye power to discover its food, as well as better wing power to overtake it after seeing it. It had fairly good jaws before, but they become somewhat enlarged and better adapted to the new work. The enlargement of the jaws and the eyes make the whole head bigger than it was before.

Of course insects do not trade places in this manner; nor does any insect suddenly change its habits. But we can easily imagine that these two forms have descended from the same ancestors and have gradually grown different, each becoming fitted for the situation in which it is placed.

It is no longer supposed that all the forms of life we now see on the earth have been distinct from the beginning, for we see evidences that many forms have arisen by the increase in numbers which establishes competition, and which in turn has compelled dispersion and forced

adaptation to new surroundings and a gradual advancement to changed conditions of life.

ORDER HEMIPTERA.

The Giant Water Bug. — This is the largest of the bugs, being two and one half inches long. It lives in the water of our lakes and rivers, but was not very generally known until electric lights became common. The light attracts them, and they are frequently found where they have fallen under the lamps. Consequently many people call them

FIG. 9. GIANT WATER BUG.
From Hyatt's *Insecta*.

the "Electric Light Bugs." They are more abundant in river towns that are lighted by electricity, and a good way to collect them is to look for them under the lamps late in the evening. By preserving them in alcohol enough may be accumulated to supply a class. They serve admirably to show the chief characteristics of bugs, and are large enough to dissect if the student wishes to learn the internal structure.

The head is relatively small and the neck is not conspicuous. The prothorax is large and broad. The outer wings are narrow in front, being separated by a triangular elevation of the mesothorax, called the scutellum. Then

for a short distance the two outer wings meet in the middle line; beyond this the wings are wider and overlap each other. The hinder part of the wings is much thinner than the front part. The inner wings are much thinner and are folded. The mouth parts are united to form a strong piercing and sucking tube, which is bent back under the head, between the bases of the front legs. The features thus far described are common to nearly all bugs. But while the majority of bugs live in the air, the water bug lives under the water most of the time, though it can, and sometimes does, come out and fly about. To fit it for swimming under the water the body is flat and boat-shaped; the second and third pairs of legs are flattened, especially the tibia and tarsus, making admirable paddles. The front legs are of no use in swimming, but are used in grasping. The water bug hides under leaves and sticks in the water, and when an unwary insect, small fish, frog, or tadpole comes near, darts out, seizes it with its powerful fore legs, and kills it by piercing it with its sharp beak. It then sucks its blood, having no jaws for chewing solid food.

The entomologists do not describe any poison glands in these insects, but it would appear that they have a poisonous effect, since they seem to kill their victims so quickly; and since this and numerous other bugs, some aquatic and some not aquatic, inflict painful wounds on man. In fact, the collector who is gathering minnows in a net is often bitten by aquatic bugs, and sometimes the hand and arm become painfully swollen as a result.

Water bugs may be seen coming to the surface, where they project the tip of the abdomen into the air. They breathe through the anal pair of spiracles.

In attempting to spread the outer wing, one usually meets difficulty, — the wing seems to be caught. There is an in-

genious catch, consisting of a little projection or hook on the side of the thorax, that catches into a groove in the under surface of the front edge of the wing.

There are two forms of water bugs common. *Belostoma americanum* has a groove in the femur of each front leg, into which the tibia shuts like a knife blade into a handle. The other form, *Benacus griseus*, lacks this groove.

The Squash Bug. — Although smaller than the giant water bug, the squash bug has the advantage of being more abundant. If the former cannot be obtained, the latter should be studied. Like the water bug, it has a small head with a sharp beak, bent back under the head and thorax. The outer wings, too, have a thickened base, with the thin hind portions of the hind wings overlapping each other. The thinner inner wings are folded lengthwise. The legs are adapted to crawling. The prothorax is large and triangular. On the under surface of the thorax are glands which secrete an ill-smelling liquid. This is a rather common characteristic of Hemiptera, and brings the "bugs" into disrepute. This is a further reason why we should not use the term "bug" indiscriminately for the term "insect." It is incorrect, and as unfair as it would be to designate all mankind by the name of one of the most disagreeable tribes of savages that could be found.

As is well known, the squash bug lives upon plants, sucking their juices through its strong, piercing beak, doing considerable damage, especially to plants of the gourd family. The eggs are laid on the under surface of the leaves about the first of July, and in August the young may be seen with the wings in all stages of development.

The Cicadas. — These insects are often improperly called "locusts." Probably they are best known by the shrill

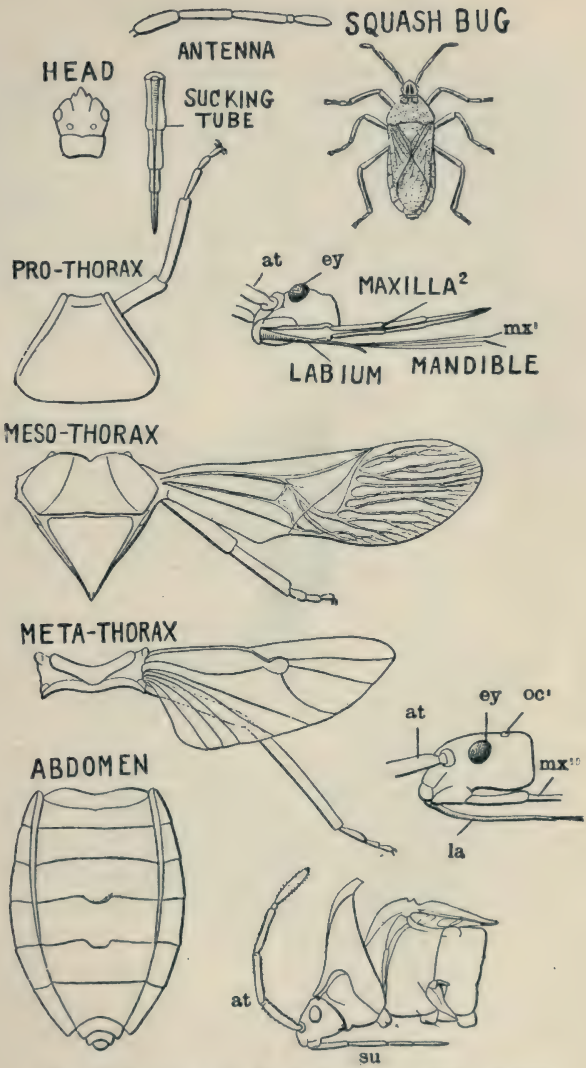


FIG. 10. SQUASH BUG, STRUCTURE AND DEVELOPMENT.

at, antenna; *la*, labium; *mx*, maxilla; *oc*, simple eye; *su*, sucking tube.

From Hyatt's *Insecta.*

sound made by the males. Under the abdomen of the males are two circular disks. Under these is the apparatus by which the sound is produced.

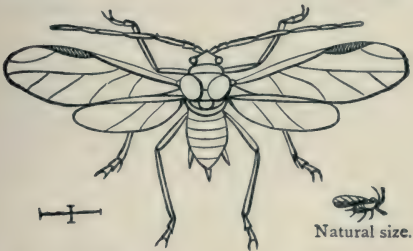
Both pairs of wings are membranous, the hinder pair being much the smaller. The larva is a grublike form which lives under the ground, sucking the juices from the roots of trees. When ready to appear in the upper world, it crawls up the trunk; and while it still clings to the bark its back splits open, and the winged insect emerges, leaving

FIG. 11. CICADA: HARVEST FLY.
From Hyatt's *Insecta.*

the empty skin adhering by the claws. Here the shed skin may remain for weeks, until washed off by the rain or brushed off by a passing animal.

The dogday harvest fly (Fig. 11) has a very broad head with eyes projecting at its angles, and is rather greenish. His shrill sound is suggestive of the dry, hot, August midday. The periodical cicada (the correct name for what is usually called the "seventeen-year locust") spends from thirteen years in the Southern form to seventeen in the Northern in the larval state. This cicada is distinctly narrower-headed than the summer cicada, and is darker in color.

Order Hemiptera. — Among the many exceedingly interesting Hemiptera we may briefly mention the chinch bugs, so well and so unfavorably known, and the plant lice, which are so common on many plants, especially on house plants. Noticeable among the plant lice is the



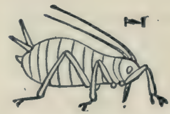


FIG. 13. PLANT LOUSE, WINGLESS LARVAL FEMALE.

FIG. 12. PLANT LOUSE, ADULT WINGED FEMALE.

From Hyatt's *Insecta.*

FIG. 14. MAPLE SCALE INSECT.

From Hyatt's *Insecta.*

grape phylloxera, so injurious to the grapevine. The scale bugs, or bark lice, are very injurious to trees; some of them are among the worst pests of the fruit grower, and tax his utmost ingenuity to prevent their spreading. The females are scalelike, and sometimes to be seen projecting from beneath the scale is the cottony egg cluster so frequently observed on maples.

Two kinds of bugs are worthy of mention as useful to man, the cochineal insect, furnishing a dye, and the lac insect, from which we get shellac. Lastly we refer to the parasitic Hemiptera, such as the various forms of lice, bedbugs, etc. Most of these forms are very degenerate in their structure, having lost their wings as a result of their parasitic habits.

Characteristics of Hemiptera. — The mouth parts form a piercing and sucking tube; the prothorax is prominent; fore wings often thickened at the base; many are ill-smelling; development direct.

ORDER NEUROPTERA.

The order Neuroptera is a small order. The only example here presented is the ant lion (Figs. 15 and 16).

Fig. 15. Ant Lion, Adult.

Fig. 16. Ant Lion, Larva.

From Hyatt's *Insecta*.

CHAPTER II.

BRANCH ARTHROPODA.

CLASS INSECTA (*Continued*).

ORDER LEPIDOPTERA.

The Monarch, or Milkweed, Butterfly. — This common butterfly is of a brown color, with black veins and wing borders. There are about two rows of white spots in the black border. This butterfly has a wing spread of about four inches. The larva is greenish yellow, with distinct bands of shiny black, and feeds on milkweeds. The chrysalid is suspended by the tip, as shown in Fig. 17.

One of the most noticeable features of the butterfly is the presence of scales on the wings and body. The scales are modified hairs, and on the body they are slender. The scales shed water, strengthen the wing, and serve as an ornament. The wings are large, and in flying act together as one wing, the wing motion being slow.

Another distinctive character is the long coiled sucking tube by which the butterfly sucks nectar from the flowers. When not in use, this tube is coiled like a watch spring and concealed between the labial palps. The sucking tube consists of the two maxillæ, much lengthened and each grooved along its inner surface, so that when the two are closely applied to each other they form a tube. The mandibles are but slightly developed.

In September or October great swarms of these butterflies may be seen, and this is a good time to collect them.

At night they settle on trees, hanging in great clusters from the leaves. It is not easy to see them at such times.

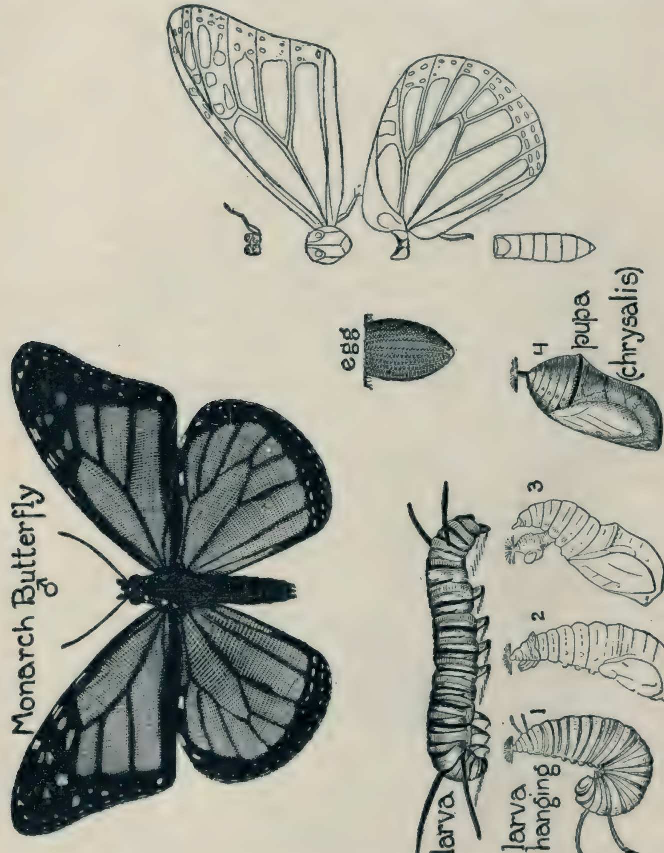


FIG. 17. STRUCTURE AND DEVELOPMENT OF THE MONARCH BUTTERFLY.

From Hyatt's *Insecta*.

They look like dead leaves. In the morning, when they are chilled, they may be taken in a net.

The Cabbage Butterfly. — One of the easiest of the butterflies to capture and to rear in confinement is the cabbage butterfly. It is white or slightly yellowish above and yellowish below. Both sexes have black tips on the anterior wings; the male has a round black spot near the outer border of each wing, while the female has two spots on each anterior wing. In the early fall, watch the female laying eggs on cabbage leaves; gather some of the leaves and watch the larvæ come out of the eggs; feed the larvæ till full grown; keep the chrysalids till the butterfly appears. Describe all the changes and note the dates of all the moltings and transformations.

FIG. 18. CABBAGE BUTTERFLY, MALE.

FIG. 20. CABBAGE BUTTERFLY. *a*, larva, *b*, pupa.

FIG. 19. CABBAGE BUTTERFLY, FEMALE.

FIG. 21. CABBAGE BUTTERFLY. Pupa.

From Hyatt's *Insecta*.

The Hawk Moth. — This moth is well known by its habit of poising like a humming bird over the flower from which it is extracting the nectar by means of its long sucking tube. It is also called the humming miller, or humming bird moth. The hawk moths have long, sharp-pointed wings and strong powers of flight. Their larvæ are usually large green "worms," one of the most common being the so-called tomato worm. The pupa is often plowed up in gardens, and is distinguished by the tongue case, which is bent around to one side of the body, like a pitcher handle. The hawk moths usually fly at twilight. The hawk moths are also called sphinx moths, from the fact that the larva often rests for a long time with the anterior end held erect.

DIFFERENCES BETWEEN MOTHS AND BUTTERFLIES.

BUTTERFLIES.	MOTHS.
1. Day-flying, usually.	1. Night-flying, usually.
2. Wings erect when resting.	2. Wings sloping when resting.
3. Antennæ knobbed.	3. Antennæ not knobbed.
4. Pupa a chrysalid.	4. Pupa (often) in a cocoon.

Development of Lepidoptera. — The egg hatches into what is commonly called a "worm." But no true worm has jointed appendages, while in these larvæ each of the first three segments back of the head bears a pair of jointed legs. These three segments become the three segments of the thorax. In addition to these legs the caterpillar, as it is usually called, has several pairs, commonly five, of soft, fleshy legs on segments farther back, almost always a pair on the last segment. These prolegs have a sort of cleft at their ends by means of which they aid in crawling. Some caterpillars are smooth, others are densely hairy.

FIG. 24. PUPA.

FIG. 23. LARVA.

FIG. 22. HAWK MOTH OR SPHINX MOTH, ADULT.

From Hyatt's *Insecta*. Larva of another species.

The larvæ eat voraciously and grow rapidly, molting several times before reaching full size. When ready to transform, the butterfly larva assumes a harder coat, commonly ornamented with silvery or gold markings (hence such a pupa is called a "chrysalid"), while the larva of the moth may spin a cocoon of silk, adding to it the hairs from its body, though some moths have a simple, dull-colored pupa which is buried in the ground. The larva has a silk gland which opens on the under lip, though many larvæ spin little or none, some making one or two loops to support themselves when changed to chrysalids, alongside or under some protecting cover, such as a limb, fence-board, etc. It should be noted that the larvæ have strong, laterally moving jaws, and eat greedily, subsisting on solid food, whereas the adult is a dainty eater, and lives on liquid food, which it takes through the sucking tube. It is common to speak of the Lepidoptera as undergoing a "complete" metamorphosis, while the grasshopper is said to have an "incomplete" metamorphosis. But as the development of the locust is just as complete as that of the butterfly, we should call the development of the grasshopper "direct," and that of the butterfly "indirect."

Kinds of Lepidoptera. — The butterflies are generally most conspicuous, as they fly in the daytime, but many of the moths are very beautiful. One group of butterflies are called from the form of their wings the swallow-tails. Though we associate the word "butterfly" with warm weather and sunny days, one species, the White Mountain butterfly, is found only high in the mountains, and the writer has been delightfully surprised to find these beautiful creatures above "timber line," near snowbanks, on the chilly mountain tops.

Perhaps most noted among the moths is the silkworm, a native of China. But we have a number of native American silkworm moths; of these the Cecropia and Polyphemus are perhaps best known. The larva of the codling moth is often found in apples. There is a large

number of related moths whose larvæ roll leaves, and are known as "leaf rollers." The "measuring worms" are larvæ of moths. Last, but not least in importance, is the clothes moth, which departs from the usual custom of living on vegetable food.

Mimicry. — The viceroy butterfly, which is sometimes eaten by birds, is protected by its resemblance to the inedible monarch butterfly. This is a case of *mimicry*.

FIG. 25. THE MONARCH BUTTERFLY.

FIG. 26. THE VICEROY BUTTERFLY, WHICH MIMICS THE MONARCH.
From Kellogg's *Zoölogy*.

General Characters of Lepidoptera. — The moths and butterflies have two pairs of scaly wings, which are large and slow in motion. The parts of the body are distinct.

The long, coiled sucking tube, composed of the two maxillæ, is a noticeable feature. The legs are small and weak, some forms having but two pairs, others having the anterior pair but not using them.

ORDER DIPTERA.

The House Fly. — The house fly has but one pair of developed wings, the second pair being represented by a pair of bodies resembling pins, that is, consisting of a threadlike stalk with a knob at the end. They are called balancers; their function is supposed to be sensory. When the fly is at rest the wings are extended backward and held horizontally over the back, lapping over each other at the inner borders, but are not folded, in the strict sense of that term; that is, are not thrown into folds, as are the inner wings of the grasshopper.

The mandibles and maxillæ are rudimentary, and the proboscis is composed mainly of the labial palps, which are developed into broad plates, which are thus adapted not only for lapping but also for rasping. They cannot bite, though they often light on the human skin to lap up the perspiration.

The wing movements are very rapid, making as many as 330 vibrations in a second. The sound produced by flies is mainly made by the vibrations of the wings; but when the fly is held by the wings, there is still heard a faint buzzing noise, and this is supposed to be due to the passage of air through the spiracles.

Development of the House Fly. — House flies lay their eggs in stable manure, each female laying about 150 eggs. In favorable weather, the eggs hatch in about one day.

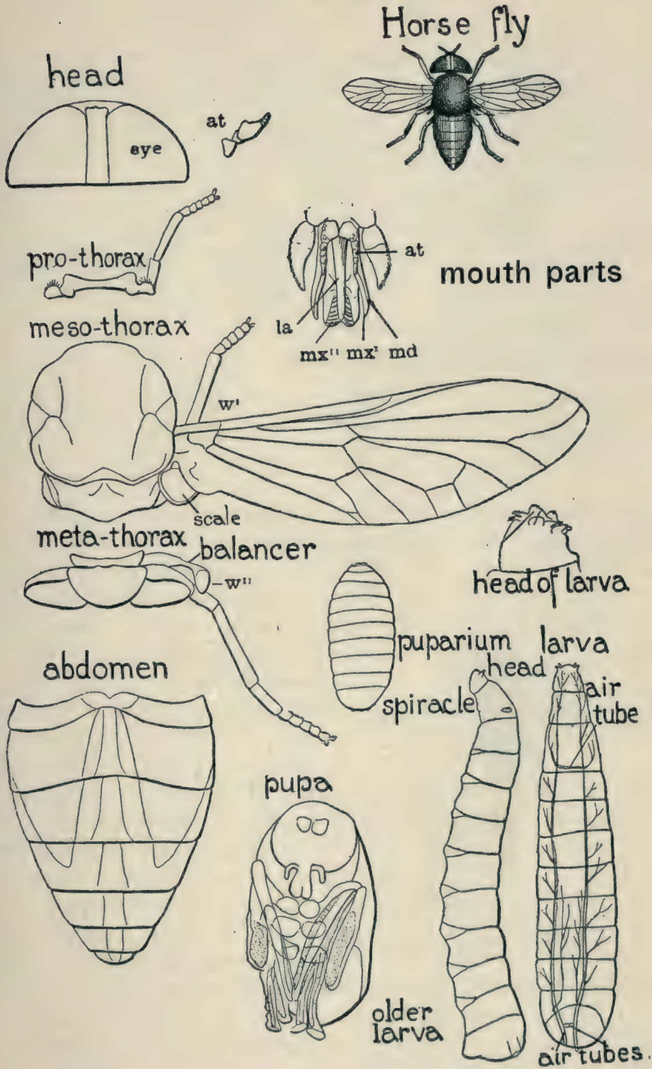


FIG. 27. HORSE FLY, STRUCTURE AND DEVELOPMENT.
at, antenna; *la*, labium; *md*, mandible; *mx*, maxilla. — From Hyatt's *Insecta*.

The legless larva is called a maggot. After living in this state about a week, it becomes a pupa, remaining in its old larval skin, which is called a puparium. (See Fig. 27.) In a week more it emerges as a fly. There may be, therefore, ten or a dozen generations in a single summer. A small number live over winter, hiding in crevices in walls and similar places. House flies are worse than mere nuisances, they are spreaders of disease. On the other hand they do much good as scavengers.

How Flies Crawl. — The fly has many little hairlike projections on its feet. These secrete a sticky substance from their ends, by means of which the fly adheres to smooth walls and ceilings.

Other Kinds of Flies. — The stable flies closely resemble the house flies, but have a sharp, piercing sucking tube. They sometimes find their way into houses, especially on warm, rainy days in the fall. On the other hand many of the flies seen about stables are house flies.

FIG. 28. THE BEE KILLER.
From Hyatt's *Insecta.*

The horseflies are well known, the most common being known as the "greenhead"; a still larger form is dull black, and in the West is called "bulldog," from its size and persistency; still smaller than either are those with banded wings, and these usually have the wings spread wider so that the fly looks triangular; some of these are called "deer flies." It is a surprise to find the big black horseflies abundant and annoying in the cold air of the high tops of the Rocky Mountains.

Among the forms that annoy man and beast are the black flies, or midges, often swarming in the Adirondacks. On account of their smallness the Indians call them "no-see-ems." To guard himself against these pests the hunter and the fisher often anoint the face and the hands with a mixture of tar and oil of pennyroyal.

Every one has noticed the big fly that occasionally is found in houses, as it attracts attention by its loud buzzing and its bluish abdomen. It is the blowfly, that lays its eggs on meat. It is a disgusting sight to behold flesh "alive with maggots," but when one reflects he sees

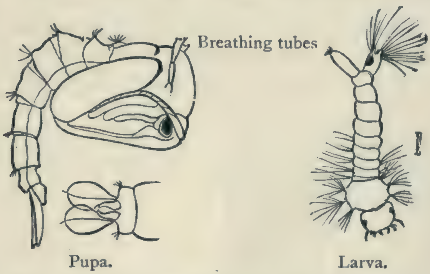


FIG. 29. DEVELOPMENT OF THE MOSQUITO.

what a wise provision of nature it is that such decaying matter should be so promptly and effectually disposed of. Let the hunter sit down to eat his lunch of biscuit and meat in any part of the Rocky Mountains, and the chances are that before he has finished the blowflies will have discovered the presence of flesh, and come buzzing around him.

The botfly lays its eggs on the hairs of horses' fore legs and shoulders. The horse gets them into the mouth from scratching itself by biting, and swallows them. The larva attaches itself by means of hooks to the inner wall of the stomach. Later it passes on through the intestine, and the pupa completes its development in the dung.

"Skippers" are the larvæ of black flies, about half the size of the house fly, that lay their eggs on cheese, ham, and bacon. Bills received from packing houses often specify that they do not guarantee their goods against skippers.

There are also flies that injure plants. Among these the Hessian fly is well known. The larva is to be found between the sheath of a blade of wheat and the stalk, where it does its damage. There is also a "wheat midge" which causes considerable loss. Nearly every one must have noticed on the ends of willow twigs a gray cone-shaped growth. This is caused by the developing larva of the "pine cone" gall gnat.

The Mosquito. — The mosquito lays its eggs on stagnant water. The larvæ are known as "wrigglers," and their well-known habits justify the

name. The larva breathes by a tube at the hinder end of the body. The pupa is also active; it breathes air through two tubes which grow out of the thorax. The piercing and sucking tube of the adult consists of several mouthpieces which fit snugly together. Only the female bites. She is a cheerful individual, singing as she goes about her work. Some excellent authorities believe that mosquitoes are the chief agents in introducing the germs of malaria into the human system. Pouring kerosene on the water in which mosquitoes are breeding will kill them, and this is probably a more practical method of reducing their number than might be at first supposed, for kerosene, like any other oily substance when on water, spreads out in an exceedingly thin film, a little of it going a long way.

Diptera. — This order of insects receives its name from the fact that its members have but two wings, as seen in the flies and mosquitoes. The life history of the house fly is fairly typical. The knobbed balancers (rudimentary hinder wings) are called "halteres."

ORDER COLEOPTERA.

The May Beetle. — This brown fellow is well known, but more commonly under the incorrect name "June bug." You will hardly need to hunt for a specimen, for if you leave your window open as you sit by your lamp on an evening in May or June, he will come to you. Instead of picking him up and throwing him out of the window, as you have been in the habit of doing, lay down your book and study him, for he will teach you more about himself than you could possibly learn from any book in the same length of time. At his best he is a poor flier, and, bewildered by the glare of light, he is more clumsy than ever; if he bumps against the lamp and falls upon the table, you will have a good look at him. Note the order in which the legs are moved in crawling. Try to pick him up and find how he

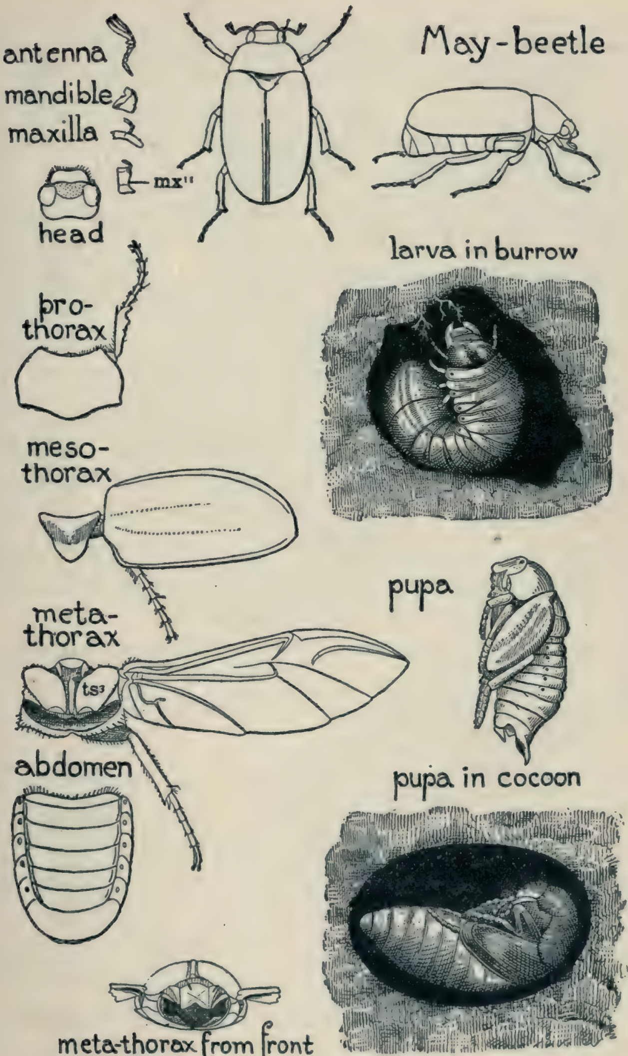


FIG. 30. THE MAY BEETLE, STRUCTURE AND DEVELOPMENT.

From Hyatt's *Insecta*.

holds on so well. Observe another one flying, — see how he holds the wing covers up and out at the sides. As soon as he lights, see how these wing covers come down over the membranous flying wings, which at first project behind the wing. Watch him tuck the wings under the wing covers; can you tell how he does it? After the membranous wings have been withdrawn from sight, pick him up and note that the wing covers meet in a straight line along the middle of the back, entirely concealing the true wings. Note also the large prothorax. The head is small, but has strong mandibles and two pairs of maxillæ. The enlarged ends of the antennæ consist of a series of leaflike plates, giving the name to a large group, — the Lamellicorn beetles. Watch him as he starts to fly again. In order to give the flying wings free play, the wing covers must be held well up and forward. In this position they make considerable resistance to flight, and it is easy to see that this kind of insect cannot be a first-class flier.

These beetles sometimes do considerable damage, by eating the leaves, especially of the cherry. In the early evening one may see swarms of May beetles and later hear them buzzing about the foliage.

The eggs are laid in the ground and hatch out into white "grubs." Every boy knows them well and uses them for bait, and often he learns that the blackbirds know enough to follow the plow and pick up the grubs that are left in the furrow. The grub usually has a dark head, with a white body, the first three segments bearing each a pair of jointed legs that correspond to the three pairs of legs of the adult beetle. The hinder part of the body is often dark from the dirt that has been eaten. Every one knows how they lie curled up and in the ground; they generally rest on their backs. They often do great

injury by eating the roots of grasses, strawberry plants, corn, grain, and other plants. The larva lives in the ground

FIG. 31. THE COLORADO POTATO BEETLE AND ITS DEVELOPMENT.
a, eggs; *b*, larvæ; *c*, pupa (underground); *d*, adult; *e*, wing cover; *f*, leg.
From Hyatt's *Insecta*.

two or three years. The last of its stay is passed in a pupa state, when it is inactive, lying in a smooth, oval cavity it has made for itself.

FIG. 32. COMMON GROUND BEETLE.
From Hyatt's *Insecta*.

The Colorado Potato Beetle. — This is too well known to need description. It is a native of the Rocky Mountain region, where it lived on a species of Solanum (to which genus the potato belongs); when the potato began to be cultivated near its home, the beetle transferred to the new plant, and, starting in 1859, it spread eastward till it reached the Atlantic coast in 1874.

The Ground Beetles. — Among the most common of our beetles are the ground beetles, to be found under logs, boards, and stones, or running about on

the ground in the summer and fall. The caterpillar hunter has green wing covers and is over an inch long. The fiery hunter has on the wing covers rows of red or copper-colored spots.

The Tiger Beetles. — These beetles get the name from their active predaceous habits, as well as from their bright-colored and yellow-barred wing covers. They run actively and fly well for beetles. They are often to be seen on the ground, especially on sand along streams. When you attempt to capture one it may remain quiet till you get near it, when it darts away, flying a short distance, and usually lights with its head toward you.

The Borers. — There are many beetles whose larvæ bore into trees, where they do great damage. Among these, perhaps the locust borer

FIG. 33. HICKORY TREE BORER; LARVA, PUPA, AND ADULT.
From Hyatt's *Insecta*.

and the painted hickory borer are found as frequently as any. The woodpeckers do good service in destroying these grubs.

The Stag Beetles. — Many children know these beetles as "pinch bugs." The large, incurved mandibles are very characteristic. The larvæ usually live in decaying wood.

The Dung Beetles. — No boy or girl who has spent much time in the country has missed seeing these odd beetles, called "tumble-bugs." On the way to and from the district school the child meets the pairs of beetles rolling the big ball that they have made from the droppings of horses and cattle. It is interesting to see them, one pushing and one pulling; as he patiently follows and watches them, he sees them at last bury the ball. Later the child learns that the female lays eggs in the ball, which the larvæ consume as food.

The "Weevils." — Some of these are small beetles, not more than one fifth of an inch long. They lay their eggs on the pea pods; the

larvæ bore their way into the pea, and eat out to the skin through which the adult easily makes his way when ready to emerge.

Blister Beetles. — A large family of beetles has a blistering substance which is used in making blistering plasters. The "Spanish fly" belongs to this group. One of the most common of our blister beetles is a black fellow abundant on goldenrod flowers.

Carrion Beetles. — These usually have club-shaped antennæ. They are well known, as both the larvæ and the adults feed on decaying flesh. Some of these beetles are called "sexton beetles" from the fact that they bury small animals.

The Rove Beetles. — These are odd forms, with short wing covers, which hardly conceal half of the abdomen. This is long and flexible, and is often carried turned up as if threatening to sting, which it has no power to do.

The Ladybugs. — All children who live in the country know these hemispherical beetles, with their smooth and often brightly colored and spotted backs. Most of them are predaceous, and one of the greatest triumphs of economic entomology was the introduction of a species of ladybug from Australia into California, where it largely checked the ravages of a scale insect, which was making havoc with the fruit trees.

The Carpet Beetles. — Some of these destroy carpets. Others are the greatest pests of museums, destroying the stuffed specimens. The best remedy is bisulphide of carbon, whose fumes are fatal to eggs, larvæ, and adults.

The Click Beetles. — Boys know them as "spring beetles," "snapping bugs," "skipjacks," etc. Lay one on its back, and soon it gives a spring, with a click, that raises it perhaps several inches. If it lights on its back, it soon tries again. These beetles, like many others, "play 'possum." Their larvæ are "wire worms," and do great damage, eating the roots of corn, grain, grasses, and other plants. One of our largest click beetles, the eyed elater, is gray, and has on the prothorax two large black spots resembling eyes.

The Snout Beetles. — These beetles (the true weevils) are very odd in having the head prolonged into a long beak, sometimes longer than the body. Most of these are known as curculios. They bore a hole with the end of the snout, deposit the egg, and then push the egg to the bottom of the hole with the snout. They destroy many fruits and nuts.

The Fireflies. — These, too, are beetles. Children do not need to be told that they emit light, and the most learned scientist cannot tell just how the light is produced. The females of some fireflies are wingless, and are called "glowworms."

Water Beetles. — Not least interesting among beetles are the water beetles. We shall notice three kinds. First, the whirligig beetles, which nearly everybody has observed on the surface of the water, whirling round and round in swarms. Like the other water beetles, they have a flattened body, and the hinder legs are paddle-shaped. The whirligig beetles occasionally dive. They have each eye divided into two parts, one of which looks up and the other down, so that one would say they had two pairs of eyes.

The predaceous diving beetles have oval bodies, somewhat wider behind. They are more abundant in stagnant water. When at rest they come to the surface and remain with the head down and the tip of the abdomen projecting into the air. Like the water bugs, they breathe by taking air under the wings, and when a new supply is needed they again come to the surface. The spiracles are on the upper surface of the abdomen. They are very voracious, and eat other insects and even small fishes. The larvæ are spindle-shaped, with sharp, incurved mandibles, and are known as "water tigers" on account of their fierceness. Both larvæ and adults may be kept and fed on meat.

The water scavenger beetles are elliptical. They do not breathe as do the predaceous water beetles, but come to the surface head up and take air under the body, where it is carried as a film, which gives a silvery gleam when seen from beneath. They are supposed to feed mainly on decaying vegetable matter, but some are known to catch live insects and eat them. They may be distinguished from the predaceous water beetles by their shape, and by a long, sharp spine that projects backward from the under surface of the thorax. Catch one of these beetles by one of the hind legs and you will probably find out the use of this spine. Though all these beetles have the power of flight, they do not usually try to escape from a jar of water. It is easy to catch them by scooping in ponds with a dip net. They may be kept in glass jars (candy jars are very convenient), and watched from below as well as from above. If they have no solid surface on which to crawl, they are not likely to get away. It would seem that they cannot start to fly from the surface of the water, but must have some solid object from which to rise into the air.

Coleoptera. — The beetles are called Coleoptera, meaning sheath-winged, from the hard, horny wing covers. The hind wings are membranous, and are usually considerably longer than the wing covers. To enable the beetle to protect them there is a joint in the anterior edge of the wing so that it can be folded crosswise as well as lengthwise. This is accomplished by moving the abdomen downward and backward, then upward and forward to draw the wing under the covers. Some beetles lack true wings and are unable to fly. The mouth parts are fitted for biting.

All insects have chitin in the skin to stiffen it, but the beetles have this most fully developed, and are the hardest and firmest bodied of insects. This is in keeping with their mode of life, as many of them crawl into crevices, under stones, logs, etc. They are the strongest of insects, and the load they can carry, in proportion to their weight, is marvelous. Beetles have compound eyes, but almost always lack the simple eyes that are present in most insects.

As the under surface of the abdomen is subject to frequent pressure, it needs to be hard and unyielding. How, then, can respiration be effected? It is secured by having the upper surface of the abdomen more soft and flexible; by the in-and-out movement of this region the air is taken in and sent out through the spiracles, which, except in water beetles, may usually be seen along the abdomen.

In a former chapter we saw how the dragon fly would have to change if he were to assume the life of a locust. Go a step farther and it will be evident that the beetle, forcing his way into crevices and into narrow places, has acquired the hard, smooth body which he requires to fit him for such a life.

There is great variety in the habits of beetles; they live in air and in water; are carnivorous and herbivorous; some

are parasitic; the larvæ are found in the earth, in decaying wood, in the living wood of hard trees, in manure, in carrion, in fruits and seeds.

Many are injurious; others are beneficial, as the ladybugs, which destroy injurious insects.

ORDER HYMENOPTERA.

The Honeybee. — Our honeybee is of European origin, and has long been domesticated. Occasionally escaped swarms live in a wild state. The three parts of the body, namely, head, thorax, and abdomen, are very distinct; but it should be noticed that the prothorax, instead of being immovably connected with the rest of the thorax, as in the fly and many other insects, is movable. Another feature, peculiar among insects, is the transferring of one segment from the abdomen to the thorax, — what appears to be the last segment of the thorax being really the foremost segment of the abdomen. The second segment of the abdomen (apparently the first) is slender, and allows the abdomen to be bent sharply forward under the thorax; and nearly every one has learned, in a way that he will not forget, how and why the bee does this.

The two pairs of wings are membranous, the hind pair being much smaller than the anterior. Along the front margin of the hind wings is a row of hooks which catch on a ridge at the hind edge of the front wings, so that in flight the two wings work as one, — in fact until the wings are unhooked there seems to be but one pair.

The mouth parts are peculiar. In most insects the mouth parts are fitted either for biting or for sucking. In the bee we find both sorts of structures. Mandibles are present, and sometimes are strongly developed. But the food of

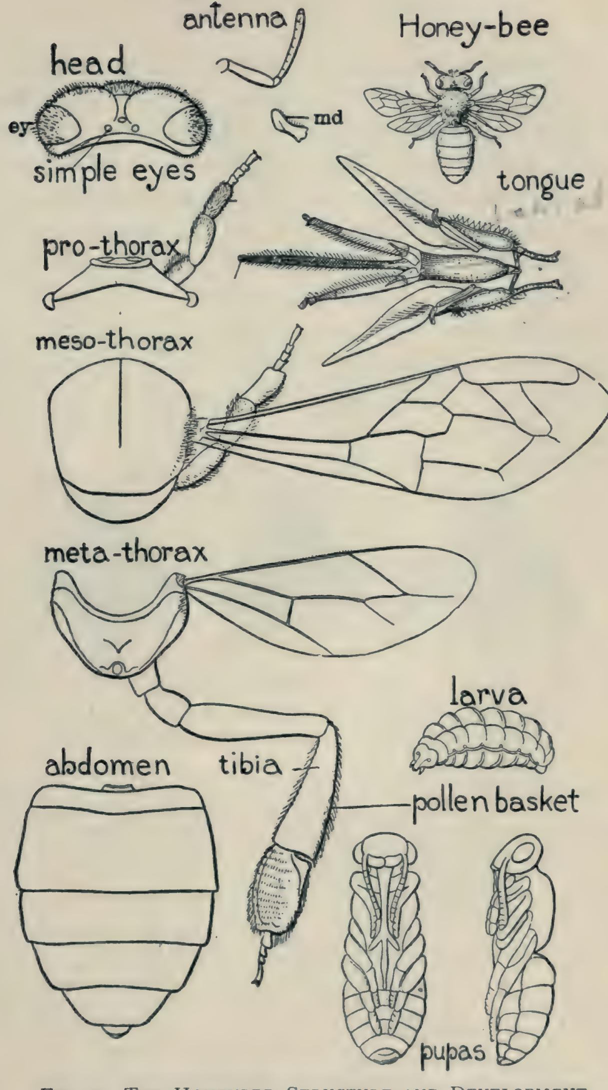


FIG. 34. THE HONEYBEE, STRUCTURE AND DEVELOPMENT.

From Hyatt's *Insecta*.

the honeybee is liquid, and the tongue is the conspicuous organ. The two maxillæ, with the two labial palps, form the sucking tube, within which the cylindrical tongue moves up and down.

The antennæ are like an arm bent at right angles at the elbow. The pollen "basket" (see Fig. 34) is on the outside of the tibia of the hind legs of the workers, and is simply a flattened segment surrounded by stiff hairs. The sting is a modified ovipositor, consisting of several pieces closely fitting together, constituting a tube, through which the poison is conveyed from the poison gland within the tip of the abdomen.

FIG. 35. HONEYBEE.
a, drone or male; *b*, worker or infertile female; *c*, queen or fertile female.
From Jordan and Kellogg's *Animal Life*.

Kinds of Bees in a Hive. — There are three forms of honeybees, — the queen or female, the drones or males, and the workers, which are undeveloped females. There is but one queen in a hive most of the time, and comparatively few drones, the great majority being workers. The average hive consists of from twenty-five thousand to thirty-five thousand bees, but there may be as many as fifty thousand. The drones have broad, blunt bodies, and have no stings; and may be further distinguished by their large eyes, which make up most of the head. They may be found in the hive in the early summer, but after the swarming

season is over they are driven out or killed by the workers. The workers are the smallest of the three kinds, and are provided with "pollen baskets" and stings. The queen is larger than the workers, and has a long, pointed abdomen. She has a sting, but never uses it except against a rival queen. The average life of a worker is about five weeks. Workers may live eight months, while a queen has been known to live five years.

The Work of the Hive. — As indicated in the name, the management of the hive falls chiefly on the workers. In the first place, the workers make honey. They gather nectar from flowers; this is taken into the honey stomach, but not mainly for the sustenance of the worker. It is transferred to the cells, loses some water by evaporation, and becomes honey. The workers make the wax from which the comb is made. The wax is a secretion from the glands on the under surface of the abdomen. When wax is needed a large number of workers gorge themselves with honey and hang like a curtain, clinging to each other, remaining quiet. As the wax exudes from the glands, other workers gather it and construct the comb. The economy of material is well known, but the cells are not always mathematically exact, as is commonly supposed.

The workers also collect a gummy substance from buds, which forms propolis, or "bee glue," with which they cement crevices and make similar repairs. Pollen is also gathered in a "basket" on each hind tibia. Of this pollen "bee bread" is made for feeding the young.

Development. — For the rearing of the young special cells are made which constitute the "brood comb." This brood comb may be afterward used for storing honey. The queen deposits an egg at the bottom of each cell, and after they hatch, the larvæ are fed by the workers till ready to

go into the pupa state, when the cell is capped over till the pupæ transform into adult (or imago) bees.

The drones, being larger than the workers, are developed in larger cells. Queen cells are larger than other cells. At the season of the year when the bees give regular attention to rearing queens, the queen cells are usually built at the bottom or ends of the comb. But if the bees are obliged to produce a queen out of the regular swarming season, the queen cells are made by tearing out the partitions and combining three cells into one, which is built out and hangs vertically in front of the comb. In the egg state there is no difference between the queen and the worker, but the larva that is to become a queen is fed on specially prepared food. In the early part of the summer several queen cells are made; as soon as a new queen is hatched the old queen tries to kill her; but the workers protect the new queen, and the old queen, followed by a part of the workers, departs to establish a new colony, and this is called "swarming." If a number of new queens are hatched at the same time, they may fight for leadership, and the one survivor rules supreme. Or, often, several young queens depart with a swarm.

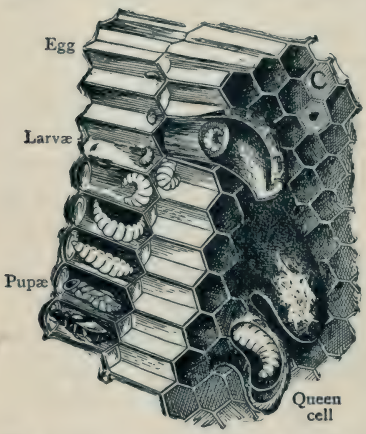


FIG. 36. CELLS CONTAINING EGGS, LARVÆ, AND PUPÆ OF THE HONEYBEE.
The large, irregular cells are queen cells.— From Jordan and Kellogg's *Animal Life*.

The queens that are thus killed are carried out by the workers, and they do the same for any that die in the hive

All dirt and rubbish are carefully removed, the hive being a model of neatness.

In warm weather a number of workers may be observed stationed at the entrance, fanning vigorously with their wings; they do this to ventilate the hive.

Bumblebees. — The queen is the only one of a colony that lives over the winter. Selecting some convenient place for a nest, usually an old nest of a field mouse, she gathers a mass of pollen and lays some eggs upon it. As the eggs hatch out the larvæ eat into the pollen, and when fully developed spin silken cocoons for themselves. After these cocoons have served as cradles they are strengthened with wax and used for storing honey. Every country boy has robbed the nests of the bumblebee; he likes the honey and is willing to pay the price for it. Nearly the whole colony of bumblebees may be captured by pouring water into the nest, which renders them unable to fly; or if a jug partly filled with water be set near the nest, when they are disturbed they usually enter the jug, and, getting into the water, are easily taken; or the whole colony may be chloroformed. Being larger than the honeybee, they offer some advantages for study.

Other Bees. — The honeybees and bumblebees are called social bees in distinction from other kinds of bees that lead a solitary life. Among the solitary bees is the carpenter bee, that tunnels into wood, sometimes a foot or more. Some bees cut out circular pieces of leaves with which to line their holes. Others dig holes in the ground; some mine into the sides of banks, one group of the mining bees being called the "short-tongued" bees. There are also several parasitic bees.

Wasps. — As with the bees, some of the wasps are social, while others are solitary. In colonies there are three kinds of individuals, males, females, and workers, all winged. The wings, unlike those of bees, are folded into plaits, as in a fan. They build nests either in the ground or on trees and buildings. Nearly everybody has seen the large nests suspended from trees, about the size and shape of a football; and perhaps many have vivid recollections of the warm reception they received when they knocked abruptly at the door of this lively community. The hornet, or yellow jacket, need not be described to a country lad. "Eternal enmity" is sworn between them, and each knows there is no use of showing a white flag. Still, the skillful teacher may capture

the entire colony by quietly slipping an insect net over the nest and tying the net to inclose them. Later a hole may be made in the tip of the net, and a single hornet at a time may be allowed to pass under a tumbler inverted on a plate. After being kept awhile they will be hungry, and if a drop of sugar water be introduced, the proud captive will not hesitate to let his enemies see how he eats. The entrance to these nests is below, while within are horizontal combs. The wasps make the nests out of wood fibers, which they tear off stumps, fences, and unpainted buildings. They chew these fibers into a pulp and make a coarse gray paper. They probably are the original paper makers.

Another wasp builds a single layer of comb, which is held horizontally under some protecting object by a narrow stalk, the comb not being surrounded by a case as with the yellow jackets. The wasps that make nests in the ground also make paper to line the nest.

Among the solitary wasps some are diggers, and it is interesting to see one of them digging a hole, throwing the dirt back as it digs very much as a dog does. Others make tunnels into the stems of plants, where the young are reared.

The mud dauber wasps are slender-waisted, and wear a suit of shiny dark blue. They have the habit of nervously jerking their wings. They are often seen lighting on the mud about horse troughs, where they are gathering mud for their nests. They make a nest of several cells, in which the eggs are deposited. We see these cells on rafters, under eaves, etc.

Some wasps store the cells with spiders and insects for the larva to feed on till it emerges. Often the insect is stung so as to paralyze, but not quite kill it.

Ants. — Here, again, we have a communistic society with perhaps a still more perfect division of labor. The males and females at first have wings, but the males are short-lived, and the females soon bite off their wings. The work is done by the workers, who are wingless. Some make a nest in the ground, while others tunnel into decaying wood. In a disturbed nest we sometimes see the workers carrying eggs. The large white objects which they carry are cocoons. Ants are very strong for their size and do a variety of work. They care for the larvæ, protect the nest from invasion by enemies; some species make slaves (and it is interesting to note that the masters are light-colored and the slaves dark). They keep cows (aphides) from which they get a sweet liquid (honeydew), and some build a cover for their herds

(cow sheds). In some forms the masters are so dependent upon their slaves that they perish unless cared for by them. Some of the ants that keep the plant lice as cows are injurious through the action of the plant lice, which feed on the roots of corn and other plants. The ants carry the plant lice, or their eggs, into holes in the ground where they survive the winter, which they probably would not otherwise be able to do. Yellow ants often invade houses, making a nest within a wall where it is almost impossible to dislodge them; these are often called "red ants." Though fond of sweets, ants are almost omnivorous.

Other Hymenoptera. — Among the other Hymenoptera we may notice the sawflies whose leaf-eating larvæ are known as the rose slug, pear tree slug, currant worm, etc. Various forms of Hymenoptera sting their eggs into the stems and leaves of plants. Around the egg is formed a

FIG. 37. LARVA OF A HAWK MOTH, WITH COCOONS OF A PARASITIC ICHNEUMON FLY.

From Kellogg's *Zoölogy*.

swelling known as a *gall*. In this the larva develops, finally eating its way out. There are many kinds of galls, and the entomologist knows the kind of insect from the characteristic form of the gall, and the adult insects are known as "gallflies."

The ichneumon flies have an ovipositor consisting of long, slender (usually three) threads, by means of which the eggs are deposited, usually in the trunks of trees, where these larvæ prey on the larvæ of other boring insects.

In the fall one occasionally sees a sluggish caterpillar covered with little oval bodies resembling eggs; examined more closely, these little bodies are seen to have a silky finish; they are the cocoons of a para-

site. A group of parasitic Hymenoptera (the Braconids) deposit their eggs on the caterpillar; the little larvæ bore their way into the big larvæ, and after consuming the tissues of the caterpillar, eat their way out and add insult to injury, attaching their cocoons to the outside of the skin. Sometimes the chrysalid of a cabbage butterfly fails to transform, and a hole may be discovered where the adult "Braconids" have made their escape.

Characteristics of Hymenoptera. — The Hymenoptera have two pairs of membranous wings, the hind pair being smaller than the front. The mouth parts are fitted both for biting and for sucking. The female usually has a sharp ovipositor, which in many cases is used simply as a sting. Development indirect.

General Characteristics of Insects. — 1. Insects have a segmented external skeleton, *i.e.* consisting of a series of rings. 2. These rings are grouped in three sets, head, thorax, and abdomen. The head bears one pair of antennæ. The thorax bears three pairs of legs and usually two pairs of wings. The abdomen does not usually have jointed appendages. 3. Insects have air tubes, branching through the thorax and abdomen, by which they breathe.

Harm done by Insects. — 1. They destroy crops, and the damage to our field and garden produce is almost beyond computation. 2. They convey disease both by getting on diseased matter and conveying it to our food, and also by introducing disease germs in biting (mosquito). 3. They injure stock (flies, mosquitoes, botflies, etc.). 4. They injure buildings (ants and white ants). 5. They are often annoying, when not injurious, to man.

Good done by Insects. — They benefit us (1) by making silk; (2) by making honey; (3) by furnishing material for making ink (galls); (4) furnish dyestuff (cochineal); (5) they are used in medicine (blister beetles); (6) their use

in fertilizing flowers is unknown to many, but is essential to man in certain crops; (7) they serve as scavengers (flies, beetles, maggots, etc.); (8) many kinds are very useful in killing injurious insects, as ichneumon flies that destroy borers, ladybugs that eat scale insects, etc.

On the whole it would be difficult for a jury to say whether insects do more harm than good; and it is perhaps best to regard them as having their place in the world to fill. And yet we must not submit tamely to their ravages, for we may outwit the robbers and turn other robbers against them. We should make it a study to turn insects, as well as other groups of animals, to the best account, and thus make the lower forms of animal life serve man, who is deservedly at the head of creation so long as he shows his fitness to rule.

ORDERS OF INSECTS.

Thysanura — Springtails.	Neuroptera — Ant Lions.
Odonata — Dragon Flies.	Lepidoptera — Butterflies.
Orthoptera — Locusts.	Diptera — Flies.
Hemiptera — Bugs.	Coleoptera — Beetles.

Hymenoptera — Bees.

CHAPTER III.

BRANCH ARTHROPODA.

CLASS MYRIAPODA.

Myriapoda. — The myriapods ("thousand legs" and centipeds) have a wormlike form, but, like other Arthropods, have a more or less hardened external skeleton, and possess jointed appendages. The head is distinct, but after it the segments are alike, there being no distinction of thorax and abdomen. On the sides or ventral surface of most of the segments are the spiracles or breathing pores, which lead to the air tubes, or tracheæ, as in the insects.

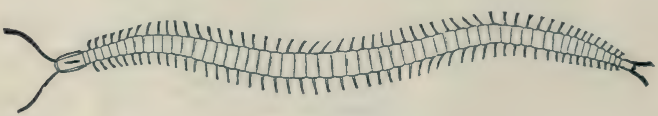


FIG. 38. CENTIPED.

The head, as in insects, appears to be composed of several segments, fused together; it bears a pair of many-jointed antennæ, a pair of eyes, and two or three pairs of jaws.

There are two principal groups, the centipeds and the millipeds. The centipeds have flattened bodies, with one pair of legs to each segment. They are carnivorous, and have a poison gland opening at the tips of the first pair of legs, which act with the mouth parts. The millipeds, or thousand legs, have cylindrical bodies, and may be recog-

nized by their habit of coiling into a spiral when disturbed; they have two pairs of legs to each segment. They are vegetarian and not poisonous.

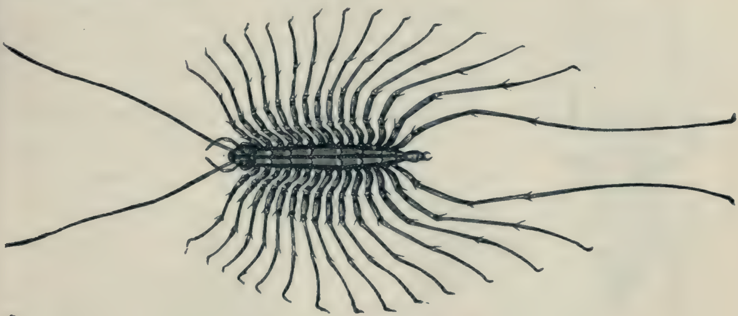


FIG. 39. SKEIN CENTIPED.

Both of these forms are usually to be found by overturning stones and logs; the centipeds seek safety by running briskly away, while the millipeds coil up and lie still.

CLASS ARACHNIDA.

The Spiders. — The body of a spider consists of two parts, connected by a constricted waist, the unsegmented cephalothorax and a large, soft, unsegmented abdomen. There are six pairs of appendages: first, the jaws, each jaw ending in a sharp, incurved segment at whose apex opens the duct of a poison gland; second, the palps, which are sometimes mistaken for a pair of legs; and lastly, four pairs of legs.

Spiders have from one to four pairs of simple eyes variously arranged on the top or front of the head. Spiders have a well-developed sense of sight, and their sense of touch is very delicate. Of their other senses little is known.

They suck the blood of insects, which they kill by means of the poison introduced through the biting jaws. Their bite is seldom serious to man, though one of the larger spiders is said to kill small birds. There is a strong sucking stomach which is worked by special muscles.

FIG. 40. JUMPING SPIDER.

In addition to breathing by air tubes, as in the case of insects, spiders also have what are called lungs, or, from their peculiar structure, "lung books." The openings to these lungs are under the abdomen. The cavity to which the opening leads is somewhat like the inside of a pocketbook, with a number of compartments. Blood flows around the outside of this lung book, and within the plates or leaves of the "book." Thus the blood and the air come near each other, separated only by a thin membrane, and by the folding an increase of surface is secured. This is the same general plan of all lungs and gills, but the details of the plan are carried out in various ways.

Like crustaceans, spiders molt, and one may often find their cast skins, looking like dead spiders, but closer examination will reveal the difference.

Spinning. — One of the most interesting of the habits of spiders is their web making. There is a great difference among spiders in this regard. Some spiders spin very little, leading a wandering life. Among these are the "jumping spiders," so named from their habit of creeping stealthily close to their victims, and then suddenly pouncing upon them. These forms are common, and their habits are exceedingly interesting. But probably most people are rather more familiar with the spiders that make

the conspicuous webs. These kinds lead a rather sedentary life, preferring to set traps for their game rather than actively hunt for it.

The spinning apparatus consists externally of two or three pairs of short segmented appendages under the tip of the abdomen. Each of these spinnerets has many short, hairlike projections, with a perforation at the tip of each.

FIG. 41. THE SPINNERETS OF THE COMMON GARDEN SPIDER.

Within the abdomen are glands which secrete a liquid substance of which the web is made. When the spider wishes to spin it presses the spinnerets against some surface, and the exuded liquid adheres; then as the liquid is drawn out into a slender thread it hardens as it is drawn, making a thread often of hundreds of strands united. The feet of the spiders have blunt claws with a series of teeth, by means of which they can easily walk on the web without tearing it. In spinning the webs with radiating and concentric lines, such as we have often noticed, the spider first spins a few foundation threads, then the radiating threads.

mouth Parts of grasshopper
2 pr maxillae
Labrum
Labium
2 palps
2 pr mandibles
1 maxillae

After this it begins at the center and proceeds spirally outward; but when this spiral web is completed it begins once more at the outside, and takes up this spiral and replaces it with a spiral spun in the reverse direction. It bites off the first spiral, and, rolling it up into little balls, drops them to the ground, hence it was formerly supposed to eat the web. The web is not placed quite vertically,

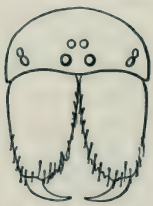


FIG. 42. HEAD AND MANDIBLES OF COMMON GARDEN SPIDER.
The spots above are eyes.

and the spider hangs on the under side, so that when a fly is caught it can run to a point over it and drop down and quickly catch it. It is usually the female that is on the web, while the male may be hidden near by. The male is sometimes much smaller than the female and generally brighter-colored.

We have often wondered how it is that on some bright, warm summer days there is so much spider web, or "gossamer," floating in the air. This is mostly formed by small spiders. They climb up on a fence or stump, or other place where there is an up current of air, caused by the heat of the sun. Standing with the tip of the abdomen pointing upward a thread is started; the current carries it upward as it is formed, and after awhile the current bears up, not only the thread, but the thread maker, — the spider itself, — and they may often be seen by the hundreds floating along, so many tiny, unpatented airships.

It is said that these gossamer webs are a sign of fair weather; so these little creatures seem to have forerun mankind in forecasting the weather as well as in aërial navigation.

Some spiders construct funnel-shaped webs, and remain concealed at the small end of the funnel, ready to rush out when their delicate sense of touch informs them that something is shaking the web, as when an insect is caught. Gently disturb such a web, and see the occupant dart forth.

Another use of the web, and almost the only use in some spiders, is as an envelope for the eggs. The web forms a silky but tough covering, usually deposited in some place of safe-keeping, but rarely carried by the mother. There

FIG. 43. SPIDER, WITH COCOON ATTACHED TO SPINNERETS.

are many eggs in one such case, and when hatched the little spiders sometimes become cannibals, each eating as many as it can of its brothers and sisters.

Kinds of Spiders. — There are many kinds of spiders; among the largest is the tarantula; the bite of this and of some other large spiders is very painful to man, but most of the stories told of spider bites are gross exaggerations. The trapdoor spider is an interesting form; it lives in a hole in the ground, lines its hole with web, and makes a lid which it hinges with the web. One spider lives under water, forming an arched web, under which it stays, carrying down bubbles of air which are introduced beneath the web.

Scorpions. — Scorpions are found in warm countries, reaching their greatest size in tropical America and Africa. The form shown in Fig. 44 occurs from North Carolina to Florida. Other species are found in the southwestern United States as far north as Kansas. The body consists of a short, unsegmented cephalothorax, followed by a twelve-segmented abdomen. The anterior part of the abdomen is broad, the hinder part narrow, ending in the poison sting.

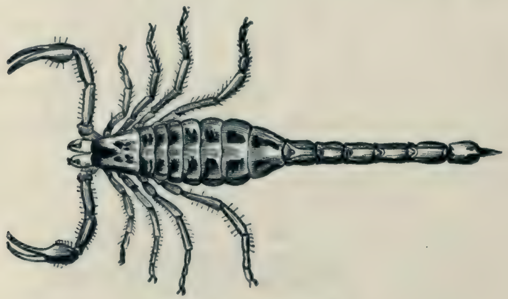


FIG. 44. SCORPION.

The sting is painful and serious to man, but seldom fatal. The scorpions are nocturnal, and feed on the blood of insects. Respiration in the scorpions is by means of lung books, as in the spiders.

Harvestmen. — The harvestmen, or daddy longlegs, are similar to spiders, but with extremely long legs. They frequent shady places, and live chiefly on small insects, such as plant lice.

Mites and Ticks. — These are small and often degenerate forms of Arachnids. Many of them are parasites, sucking the blood of mammals, as ticks on dogs, cattle, and even man. Among the mites is the "itch mite," which has been made rare by the spread of "soap and civilization."

CHAPTER IV.

BRANCH ARTHROPODA.

CLASS CRUSTACEA.

Example — The Crayfish.

Occurrence. — Crayfishes are found fairly abundant in streams and ponds in many parts of the United States. They may be seen crawling about on the muddy bottom, but, being nocturnal in their habits, they usually escape observation during the daytime by hiding in holes, under stones, and especially under ledges of rocks, overhanging banks, or where the stream has washed out the soil about the roots of trees standing on the banks.

Crayfish Holes. — Crayfishes are also found in holes which they dig, usually in low ground. When the water dries up from the ponds and creeks, crayfishes often dig down to water, and, at this season, live in these holes. The holes are frequently many feet deep. The soil and clay are brought up in pellets, and with these a "chimney" is built up around the mouth of the hole.

How the Crayfish Walks. — The crayfish walks by means of the last four pairs of thoracic legs. Each of these legs has seven segments; and the successive joints admit of motions in different planes, so that the whole appendage has great freedom and variety of movement. The crayfish usually walks slowly, holding out the big pinchers in front. It can, however, walk sideways or backward. When taken out of water the crayfish walks with a heavy, awk-

ward movement, frequently bumping its body upon the floor; it evidently needs the buoyancy of the water to support its weight.

How the Crayfish Swims. — Swimming is the most rapid action of the crayfish, and it probably seldom resorts to this means of locomotion except to escape enemies. The side parts of the "tail fin" are spread out as wide as possible, and the whole abdomen is suddenly and forcibly bent down, under, and forward. This makes a powerful stroke, and drives (or rather pulls) the crayfish swiftly backward. The whole of the under surface of the abdomen is concave, thus getting a good hold on the water. As the animal darts backward the resistance is greatly reduced by the convexity and smoothness of the dorsal surface of the abdomen. Again, since the big pinchers rather necessarily extend forward, it would be difficult for the crayfish to move forward with any considerable speed; but when it darts backward the big claws drag along in the wake without any special resistance. It should be further observed that when the crayfish is frightened, the chances are that it is on or near the bottom, which in most cases is more or less muddy; when the powerful tail stroke is made, it would naturally sweep close to, if not actually touch, the muddy bottom. This stirs up the mud, and thus makes the water turbid between the pursuer and the pursued, and greatly favors the chances of escape.

The Muscles of Locomotion. — The muscles which move the appendages are inclosed in the framework along the ventral surface of the cephalothorax. The muscles which flex and extend the abdomen in the act of swimming fill most of the space in the abdomen. As would be expected, the extensor muscles are much smaller than the flexors. The extensors arise from the side walls of the thorax, and

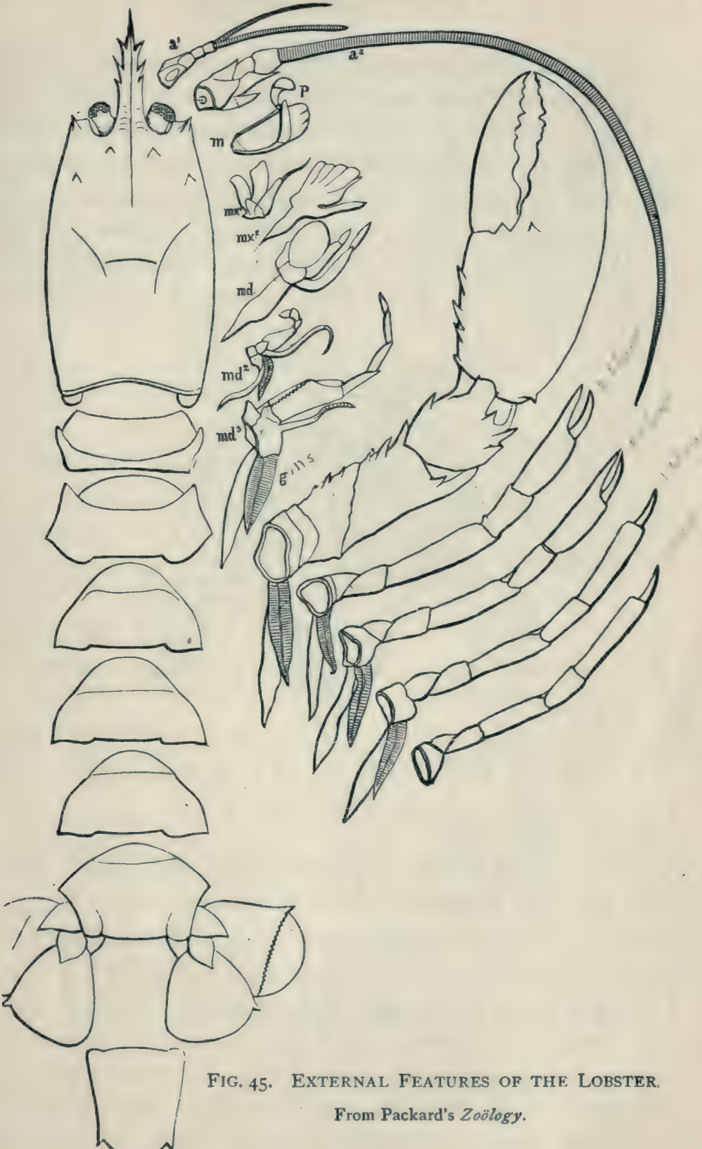
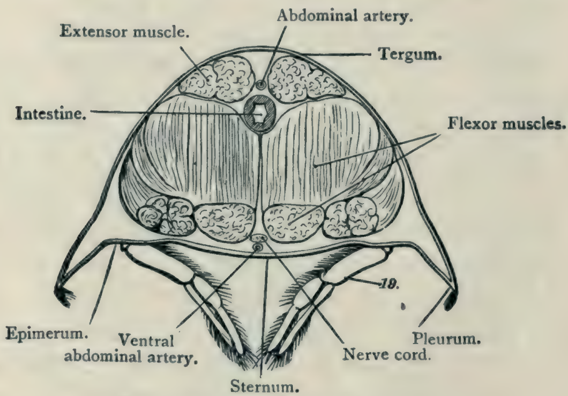


FIG. 45. EXTERNAL FEATURES OF THE LOBSTER.

From Packard's *Zoölogy*.

extend back into the abdomen, being attached to the anterior edges of the abdominal rings in the upper part of the abdomen. When these muscles shorten they pull the anterior edge of each tergum under the posterior edge of the preceding tergum, and thus straighten the abdomen. The extensor muscles lie above the intestine. Below the intestine, and filling out most of the space of the abdomen, are the flexor muscles. These are very complicated. Like the



19, one of the swimmerets.

FIG. 46. CROSS SECTION OF ABDOMEN OF CRAYFISH.
From Huxley's *Crayfish*.

extensor muscles, they originate in the thorax, and extend back and are inserted on the sternums; and when they shorten, they flex the abdomen, giving the powerful stroke by which the animal swims backward so rapidly.

Food of the Crayfish, and Mode of Eating. — The crayfish lives largely on worms, the larvæ of insects, with which most waters abound, snails, etc. The crayfish is carnivorous by choice, yet by necessity may be almost omnivorous. It is a greedy eater, and does not disdain carrion. It is de-

cidedly useful as a scavenger, disposing of a great amount of dead and decaying material which would pollute the water, such as dead fish, clams, etc. In eating, the big pinchers may tear the food to pieces, and then the smaller pinchers of the second and third pairs of legs may transfer the pieces to the mouth, the entrance to which is surrounded by the maxillipeds. Or, instead of this process, the crayfish may apply the mouth directly to the food, and gnaw it off in bits by means of the mandibles and maxillipeds. Crayfishes are frequently guilty of cannibalism.

The Digestive System of the Crayfish. — The mouth of the crayfish is on the under surface instead of at the front of the head, as in many animals. There are six pairs of mouth parts, — the mandibles, two pairs of maxillæ, and three pairs of maxillipeds. These jaws all move sidewise; and when all of them are closed, the third or hindmost pair of maxillipeds cover all the others. The short gullet passes straight up from the mouth to

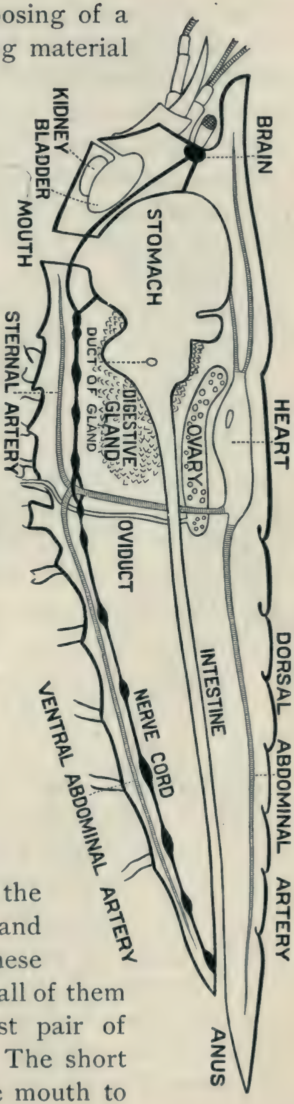


FIG 47. LONGITUDINAL SECTION OF A CRAYFISH.
Showing digestive, circulatory, reproductive, excretory, and nervous systems.

the stomach, which is situated in the head. The stomach is very complicated. It has in its walls a set of arms or levers so jointed together as to support the walls of the stomach. Further, these bars, which are composed of chitin, are acted on by sets of muscles on the outside.

There are teeth on the inner walls of the stomach, some projecting inward from each side and some from the upper surface. Certain muscles attached to the outside of the stomach act in such a manner as to make these teeth work together and masticate food in the stomach. The function of the stomach is wholly masticatory, and it has no digestive function. At the hinder part of the stomach there is a series of stiff hairs which act as a strainer, so that only very fine particles are allowed to pass on into the intestine. Alongside the stomach on each side is the large digestive gland. Each of these opens by a duct into the intestine just back of the stomach. These glands were formerly called livers, but in function they more closely resemble a pancreas, their secretion digesting proteids and fats, and perhaps also starches. Beyond the stomach the intestine extends in a nearly straight course along the upper part of the abdomen, ending in the anus on the under surface of the telson.

Respiration in the Crayfish. — The crayfish breathes by means of the plumelike gills, which are covered by the sides of the carapace. Each gill has two blood tubes in its stem, through one of which the blood enters, while it returns through the other tube. In the feathery branches of the gill the blood is separated from the water by merely a thin membrane, so that the blood and the water make an exchange, the blood getting oxygen from the water, and giving to the water the waste products — such as carbon dioxid — which it contains.

There are Two Sets of Gills. — One row is attached to the bases of the thoracic appendages; these are the foot gills. A second row arises from the joints by which the

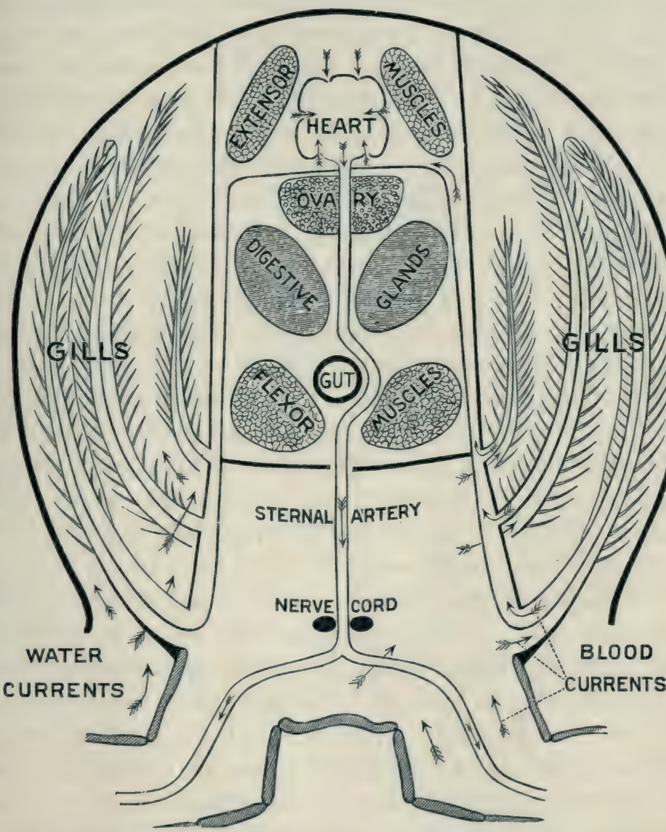


FIG. 48. CROSS SECTION OF A CRAYFISH THROUGH THE HEART.
Showing the gills, blood currents, and water currents.

thoracic appendages are attached to the thorax; these are the joint gills. (In the lobster there is a third set,

higher still, arising from the side of the thorax, and called the wall gills.) The lowest set, the foot gills, have leaflike extensions along their borders, which perhaps serve to keep the filaments of the gills from becoming entangled with one another. The gills all have their free ends extending upward. The direction in which the gills extend is in keeping with the fact that the water which bathes the gills enters about the bases of the legs, and, passing over the gills, escapes near the anterior end of the cephalothorax, back of the base of the antenna of each side. It has been observed that the cephalic groove marks the distinction between the head and the thorax. This groove also marks the anterior limits of each gill chamber. In the extreme anterior part of the gill chamber, extending obliquely upward and backward, is the gill paddle or gill scoop. It is a part of the second maxilla. It is attached by its middle part, and each end is a somewhat spoon-shaped paddle. By a constant back-and-forth motion this paddle continually bails the water out at the anterior end of the gill chamber, and thus draws more water in at the lower border of the gill cover, between the bases of the thoracic legs.

Circulation in the Crayfish. — The heart is situated in the dorsal part of the cephalothorax. From its anterior end arise five arteries: a single artery in the middle line supplies the eyes; back of this a pair run to the antennæ; and, still further back, a pair lead to the digestive glands of the two sides. At the posterior end of the heart arises one artery, which almost immediately divides into two branches; the first branch runs straight back, just above the intestine, and is called the dorsal abdominal artery; the other branch extends downward, passing through the nerve cord. After passing through the nerve cord it again divides into two branches, one running forward, the sternal

artery, and the other extending backward, the ventral abdominal artery.

All these arteries divide and subdivide, forming capillaries. But the capillaries do not reunite, forming veins; they empty into more or less irregular spaces in the body, around the muscles and other internal organs. All these spaces, or sinuses, as they are called, lead into one main channel, the sternal sinus, which extends along the middle of the ventral region. From this sinus, passageways conduct the blood to each gill. In each gill one tube, the afferent vein, conveys the blood to the gill filaments; while another tube, the efferent vein, returns the blood to another set of veins, called the branchio-cardiac veins, which lead to the pericardium. There are no tubes to convey the blood into the heart, but the blood enters the heart directly through three pairs of holes, one on each side, a pair on top, and another pair below. These holes have lips on the inside, which act as valves, allowing the blood to enter freely, but preventing a reflow through the holes. Thus the beating of the heart causes a constant flow of blood in one direction: first to the tissues of the body in general, where it gives up oxygen and food materials and picks up carbon dioxid; then to the gills, where it gives off carbon dioxid and gains oxygen; then back again to the heart. The blood is colorless, but after exposure to the air it turns bluish.

Excretion in the Crayfish. — In connection with the study of the gills we have seen how the carbon dioxid is removed from the body. But the nitrogenous wastes are excreted by a pair of kidneys, which are called, on account of their color, the green glands. They are situated in the head, just below and in front of the stomach. The gland proper is a button-shaped body, lying close to the ventral body

wall. This leads into a thin sac, which serves as a bladder, and it in turn opens by a duct to the exterior, through the apex of a hard, white, conical papilla, on the ventral surface of the base of each antenna.

It is worthy of notice that the current of water coming from the gills passes directly by this other exit of waste, so that one stream carries away all the waste products, avoiding duplication of machinery.

The Nervous System of the Crayfish. — The nervous system consists of a nerve cord which lies on the floor of the body cavity, extending the whole length of the body in the middle line. It is a white cord, composed of a ganglion for each segment, connected in line by nerve fibers. The cord is really double, but the two rows of ganglions have consolidated, so that there appears to be but one row of ganglions. The cord itself, between the successive ganglions, while apparently single, is actually double. And in two places the double nature of the cord is manifest. The two parts of the cord pass on the right and left of the gullet, forming what is called the esophageal ring, or esophageal collar; again, the sternal artery passes between the two halves in the interval between two of the ganglions. Though there is a ganglion for each segment, there is a consolidation, so that there are but thirteen distinct ganglions for the twenty (or twenty-one) segments. The first ganglion, called the brain or the cerebral ganglion, is the result of the fusion of three pairs of ganglions. Back of the gullet, and connected to the brain by the two commissures passing on either side of the gullet, is a large ganglion, which is evidently composed of the ganglions of the last three cephalic segments united with the ganglions of the first three segments of the thorax. Following this are five more distinct ganglions in the thorax and six in the

abdomen. In the abdomen the nerve cord is in plain view when the abdominal muscles have been removed. But in the thorax the cord is concealed in a groove made by the

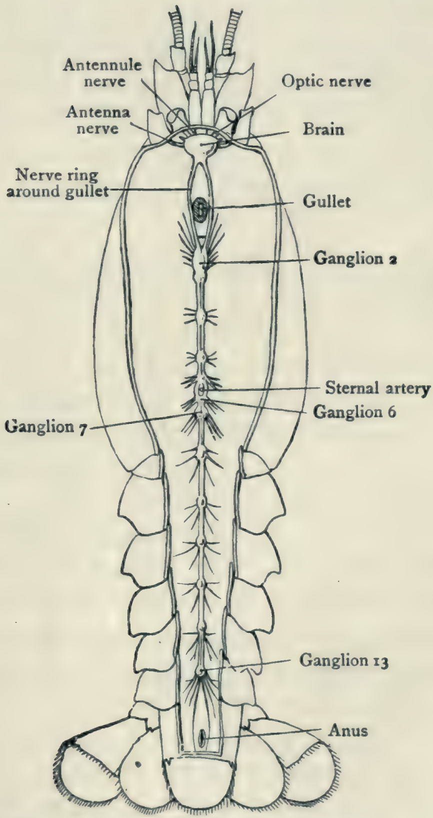


FIG. 49. NERVOUS SYSTEM OF CRAYFISH.
From Huxley's *Crayfish*.

inward projecting framework which supports the muscles which move the appendages. From each ganglion nerves radiate to supply the adjacent muscles and sense organs.

The Senses of the Crayfish. — The crayfish appears to have the senses of touch, sight, taste, and smell.

The Sense of Sight. — The eyes are on movable stalks. The advantage of being able to project the eyes is apparent. The protection afforded by withdrawing the eyes is almost equally apparent when we consider that crayfishes fight fiercely with each other, besides being frequently under the necessity of protecting themselves from enemies outside of their own race. The projecting rostrum and the sharp blade of the lamina of the antenna need no explanation as to their use. The eye of the crayfish is a typical compound eye. It is made up of distinct parts, each of which is called a facet, or cornea.

The Sense of Touch. — One does not need to experiment long with crayfishes to be sure that they feel as well as see. The general surface of the body is more or less sensitive to touch, but with such a hard covering this sense can hardly be other than a very dull sense over most of the area. But the antennæ are specially adapted for this sense, and their long, slender, tapering form and jointed structure render them convenient to apply to surrounding objects.

Smell and Taste. — Certain hairs of the external branch of the smaller antennæ are believed to be connected with the sense of smell.

There is in the basal joint of each antennule a sac, formed by the depression of its outer surface, so that free communication is left with the surrounding water. This was long supposed to be an organ of hearing, but is now regarded as the seat of the sense of equilibrium.

There is no doubt that the crayfish discriminates in choice of food, and we have good reason to believe that the sense of taste is present.

The Enemies of the Crayfish. — Various carnivorous fishes, such as black bass, eat crayfishes, hence the fisherman also becomes an enemy of the crayfish by capturing it for bait. Raccoons are very fond of crayfishes. Both of these animals are nocturnal in their habits; so when the crayfish sets out in the evening to get a lunch, the raccoon lunches on the luncher. One who frequents the woods may see the raccoon tracks along the creeks where it has been seeking this and other aquatic animals for food. Muskrats and crows are also among the more important enemies of the crayfish.

How the Crayfish escapes its Enemies. — In the first place its nocturnal habits keep it out of sight of some enemies. Second, its color is in close harmony with its surroundings, so that it is very inconspicuous. Dull shades of green, brown, and red are the prevailing colors.

Though the senses of the crayfish are none of them very acute, they plainly are useful in making the animal aware of the approach of enemies. Then it is usually near the bottom, where there are many places of refuge. And last, but not least, this creature has one kind of locomotion that is speedy, that of swimming. The hard covering may make the crayfishes objectionable as food to many animals that otherwise would eat them. The big pinchers, too, which he knows so well how to use, are no mean defense against his lesser foes. And further, the threatening attitude which the crayfish assumes when cornered, may intimidate some would-be assailants who do not like the looks of the bristling claws, and fear that the "bite will be as bad as the bark."

The Eggs of the Crayfish. — The eggs are extruded as usual, but instead of being left in some place of deposit, are attached to the mother by being glued to the

swimmerets. The eggs are small and smooth, reddish or dark, and in the mass suggest the appearance of a berry; hence the mass of eggs is called the "berry." A lobster with the eggs attached is called a "berry lobster." From the eggs hatch the little crayfishes, which have the form of the adult. These little fellows have incurved hooks on the ends of their claws, by means of which they take fast hold of the swimmerets of the mother and remain so attached for some time.

Rate of Growth of Crayfishes. — The crayfish is about a quarter of an inch long when hatched. At the end of the first year it is about an inch and a half long. After the first year it grows more slowly, and seldom becomes more than five or six inches in length.

Molting. — Since the hard parts are on the outside, such creatures would soon reach a limit of growth unless some special provision were made. This is provided for by the shedding of the entire outer hard covering at stated periods. The hard shell splits across the dorsal surface at the junction of the cephalothorax and abdomen. The carapace also usually splits part way forward from the transverse opening above mentioned. By severe effort the cephalothorax and its appendages are first extracted; then the abdomen is pulled out of its hard covering. This is a critical period in the life of the crayfish. Sometimes the big pinchers are broken off in the effort to get them out of the old case. Crayfishes sometimes perish in the struggle to get free from their "hide-bound" condition. And for some time after molting the body is soft, and hence almost defenseless. At this time the animal is unusually timid, and lives in hiding till its skin again hardens by the addition of limy matter. After shedding, the crayfish is doubly helpless; not only is his body soft and easily

injured, but his claws, being soft, are useless as weapons of defense. In molting, the hard lining of the stomach, with the stomach teeth, is also shed. Crayfishes molt several times the first year, the number of molts gradually decreasing till in adult life the molt probably takes place but once a year.

"**Crab's Eyes**." — Previous to the time of molting there appear on the sides of the stomach two button-shaped bodies of limy material. In molting they are shed into the cavity of the stomach, together with the lining of the stomach. It is believed that they break up, become dissolved, and are absorbed and then deposited as stiffening matter in the chitin, which makes the basis of the enveloping crust.

Restoration of Lost Limbs. — Crayfishes often lose their legs while fighting. Sometimes also they seem to drop them or throw them off when badly frightened, but perhaps they are merely snapped off in the violent effort to escape. The legs seem to break off always at the same place, where the leg is most narrow, and this is the easiest place to heal. The blood quickly coagulates, and such loss seems not to be dangerous or even serious. The mutilated stump at once begins to grow a new leg, but for a long time it is smaller than its mate. If one looks over a number of crayfishes, he is pretty sure to find some in this condition. The big fighting limbs are ordinarily the ones that have been lost.

Are Crayfishes Beneficial or Injurious to Man? — Crayfishes are good to eat, the only part, of course, being the muscle, most of which is in the abdomen. They are used as food to a considerable extent in Europe, but they are little used in this country. Crayfishes are very useful as scavengers, eating dead fish, etc. Crayfishes are said to benefit some heavy, clayey land by the holes they dig, perhaps by making the soil more porous and helping to drain it.

On the other hand, crayfishes often do very great damage by digging holes in the dikes and levees along the lower Mississippi. These holes gradually become enlarged, perhaps by muskrats, and may finally cause the levee to give way, inundating vast tracts of land which are protected by the dikes, and causing immense loss of property and sometimes of life.

Distribution of Crayfishes. — Crayfishes are fairly common throughout the United States, more especially in the central and southern portions. They are usually more abundant in regions where there is plenty of limestone, and are less abundant where granite rock prevails, as in New England. They are to be found in Ireland and England and on most of the continent of Europe, in Australia, New Zealand, Madagascar, and Japan. But they occur in very limited areas in Asia and South America. In Africa none have ever been found.

Origin of Crayfishes. — It is supposed that the crayfishes are descendants of marine crustaceans; that some of these forms lived about the mouths of rivers, gradually became accustomed to partly freshened water, and in time to fresh water, and ascended the streams and entered lakes. We do not know any living salt-water crustacean from which the crayfish is supposed to have been derived.

CHAPTER V.

BRANCH ARTHROPODA.

CLASS CRUSTACEA (*Continued*).

Lobsters. — With a few unimportant exceptions, the structure of the lobster is essentially the same as that of the crayfish. The lobster may be said to be a big salt-water crayfish, or the crayfish a small fresh-water lobster. Lobsters are an important food product of the North Atlantic, both to the old world and the new. From twenty to thirty millions are caught annually along the coasts of New England and Canada. They are captured by sinking large wooden traps, which are called "lobster pots." These are baited with refuse fish. A buoy is attached to each trap to mark its place, and to serve as a means of taking up the trap. The lobsters thus caught average less than four pounds in weight, but specimens have been found that weighed as high as thirty-nine pounds.

Shrimps and Prawns. — Two other marine crustaceans that are largely used as food are the shrimps and prawns. These are essentially like the crayfish, but differing from it more than the lobster. They are caught in large numbers, and eaten fresh or canned, as is the lobster. Prawns have a permanent hump on the dorsal surface of the abdomen; and the dorsal surface rises as a sharp ridge, perhaps to diminish resistance, and thus increase its speed when swimming. Most of our so-called shrimps, out of which the famous salad is made, are really prawns, and not shrimps.

Crabs. — Though differing considerably in appearance, crabs have the same essential structure as crayfishes and lobsters. The cephalothorax is broad instead of being relatively long and narrow. The abdomen is kept folded under the cephalothorax, and is not used in swimming, almost its only use being to protect the eggs in the female. As in the preceding forms, there is the hard protecting crust; stalked eyes; several mouth parts; five pairs of large thoracic appendages, the first pair armed with big pinchers; gills on

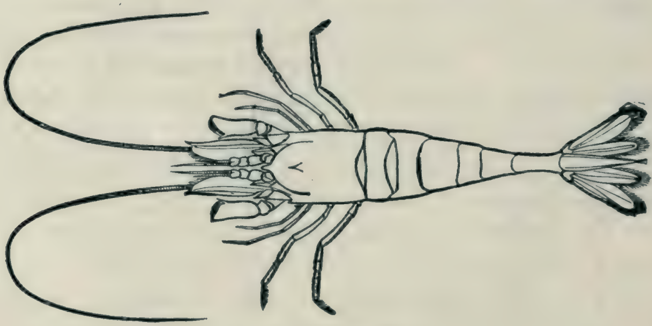


FIG. 50. SHRIMP.

the sides under cover of the carapace; and the same general manner of life. Crabs are great scavengers; and if, while at the seaside, one wishes to clean a skeleton, if he puts it into a box guarded by slats, with spaces just wide enough to let crabs in, they will do the rest. Crabs may be caught by tying a piece of meat to a string and letting it down off almost any wharf or rock into the water. When the crab takes hold with the pinchers he will usually hold on till he reaches the surface; and while he may be lifted out on the wharf or bank, it is safer to use a net when he is brought to the surface. Though most crabs are good to eat, and many kinds are so used, the one most eaten is the blue crab

(*Callinectes hastatus*), often called the "edible crab." Just after they molt they are esteemed good, cooked whole, under the title "soft-shelled crabs."

Swimming crabs, such as the blue crab, have the last pair of thoracic legs developed as paddles, by means of which they swim sideways with considerable rapidity. In the

FIG. 51. LADY CRAB, NATURAL SIZE.

case of crabs that do not swim, the last legs are not flattened, but end in a point like the other legs. The little oyster crab is often found in an oyster stew (Fig. 52).

Development of the Crab. — It is very interesting to note that the crab, when first hatched, has nearly the form of the crayfish, with an extended abdomen and a relatively narrow body, but that gradually the cephalothorax widens, and the abdomen becomes folded under the body. Crabs

are regarded as the highest, and probably the latest, of the crustaceans. While the development of the individual does not recapitulate the development of the race quite so fully as in some other groups, it serves very well to illustrate the general law that the development of the individuals of the highest group is an epitome of the development of the group as a whole, and often is a recapitulation of the order of geological succession.


FIG. 52. OYSTER CRAB.

Cephalization. — By this term is meant the higher development of the head, and of the appendages belonging to and immediately surrounding the head. In the lower forms of crustaceans the head does not predominate as in the crabs. The diameter is approximately the same from one end to the other. Even in the crayfish, the ganglion at the anterior end is very little larger or better developed than those of the abdomen. In the crabs there is a much greater concentration of the ganglions in the thoracic region. This principle will be illustrated in other groups of animals, but it can be seen here that the higher in the scale, the greater is the development of the head regions.

The Sand Crab. — This crab, with numerous others, lives out of the water considerable of the time. It is sandy in color, and lives out on the beach. It seems to be rather keen sighted, and runs at a lively rate when pursued. It usually attempts to escape, and often succeeds, by burying itself in the sand. This it does in a wonderfully short time. With a few quick, jerky motions of its legs it buries itself, usually leaving only the tips of its two eyes projecting above the surface. It is practically concealed, — so much so that one who has pursued it, unless he looks closely, may lose sight of it; but the crab has its enemy in sight all the time. Its means of escape is ingenious, and the color is a fine example of protective resemblance.

The Fiddler Crab. — This little crab, about two inches wide, has one big and one small pincher, suggesting the fiddle and bow. These very interesting little fellows are sometimes so thick on the shore, along the water line, that they crowd each other for crawling room, and make a very noticeable rustling noise as they elbow each other while retreating from the inquisitive biped, of whose motives they are suspicious.

Blind Crayfishes. — In the Mammoth Cave, and some other caves, are found blind crayfishes. This does not mean that in all cases eyes are completely lacking, — in fact, in most cases rudiments of eyes are present, but useless. How long these animals have thus lived in darkness we do not know; but we find that an organ that is no longer used may lose its function and even dwindle away. We here see illustrations of the general law that disuse leads to deterioration in both structure and function, often resulting in complete uselessness, and perhaps complete atrophy as well.

Hermit Crabs. — These crabs back into an empty univalve shell, which they carry around with them for protection. The abdomen, and all the

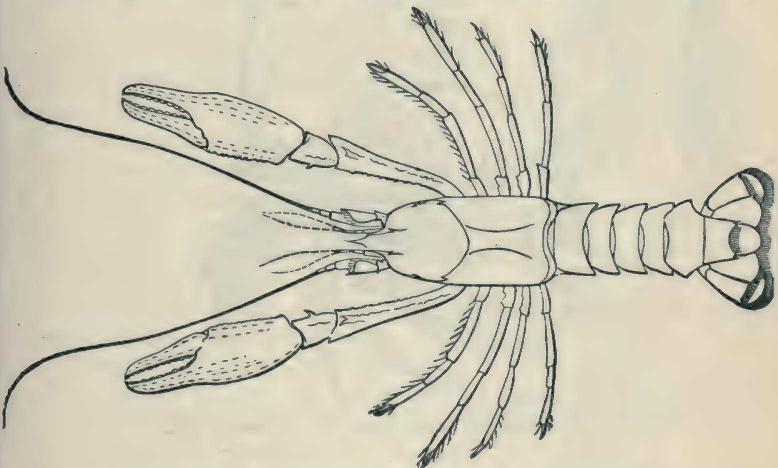


FIG. 53. BLIND CRAYFISH OF MAMMOTH CAVE, NATURAL SIZE.

parts except the head and projecting appendages, become soft, and dependent upon a continuance of such protection. When the crab gets too big for the shell, he hunts for a bigger one. It is said that these crabs sometimes fight over shells. One hermit meeting another crab that has a shell that he thinks would fit him better than the one he has, ejects the other fellow, perhaps only to find that he has gotten a misfit after all, and so goes back to his old shell, a wiser if not a better crab.

Barnacles. — If one lies down on the edge of almost any stone pier or wharf along the coast and looks down into the water, he may see a

general wavelike motion as if hundreds of hands, with feathery fingers, were constantly opening and closing. Looking closer, he will see that these feathers are in clusters, each projecting from the apex of a cone-shaped body whose base is attached to the rock wall. These are acorn barnacles. Disturb them and they will draw in their feathery appendages and close the shelly valves that guard the opening. They resemble bivalve mollusks, and in fact were regarded as mollusks until it was discovered that when young they are like the young of the lower crustacea. After leading a free-swimming life for a time, they attach

FIG. 54. HERMIT CRAB IN SHELL OF SEA SNAIL.

themselves by the head end to a rock, and thenceforth live anchored to this one spot. They have given up locomotion, and become sessile. The law of progress in evolution is toward greater freedom, as illustrated in many forms of animal life; but here we have a good example of retrograde development, or degeneration. Almost the only ready indication of its crustacean relationship is the segmentation of the appendages.

Another form of barnacle is the goose barnacle, which has a body resembling a clam, attached by a soft, flexible stalk to some solid object, frequently to a piece of floating timber. When actively feeding, the shell opens and the feather-like feet extend in lively motion, but

they are withdrawn and shut in if the animal is disturbed. In its development the goose barnacle has about the same history as the acorn barnacle.

Other Degenerate Crustaceans. — Degenerate as are the barnacles, there are still lower crustaceans. Various crustaceans have become parasites, living attached to whales, fishes, etc., and have become so degenerate as to have lost all likeness to the typical crustacean structure, so that no one would, without prolonged investigation, even suspect that they belonged to this group.

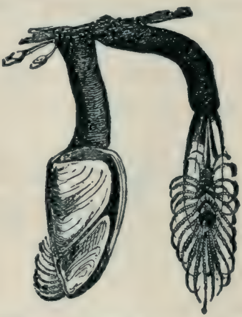


FIG. 55. GOOSE BARNACLES. From Kingsley's *Comparative Zoölogy*.

All of the above cases, blind crayfish, hermit crab, barnacles, and parasitic crustacea, illustrate one general principle, that disuse leads to atrophy, and that parasitic habits involve degeneration in structure as well as in function.

Classification of Crustacea. — The crustacea are divided into two subclasses, the Entomostraca and the Malacostraca.

The Entomostraca are of comparatively simple structure, usually small, sometimes microscopic. The number of segments is variable, and the appendages are very similar throughout. We may briefly consider some of the leading orders.

Some of the Phyllopoda are covered by a flat, shield-shaped carapace; others have a bivalve shell which does not inclose the head. Some Phyllopods have no carapace. In some forms the body is unsegmented, and there are leaflike, lobed, swimming feet.

The Ostracoda are small and the head as well as the rest of the body is inclosed in a bivalve shell, somewhat resembling a little clam.

The Copepoda may be represented by the cyclops, or water flea, Fig. 56. This form is common in sluggish streams and ditches. It is white, large enough to be seen by the naked eye, and swims by a jerky motion of the antennæ, which are its largest and strongest appendages. The female bears two large egg masses.

The Cirripedia comprise the barnacles above mentioned.

The Malacostraca comprise the higher Crustacea. They are usually of considerable size, and the number of segments is rather constant, instead of variable as in the Entomostraca. There may or may not be

a carapace, and the head may consist of but one piece, formed by the consolidation of several segments (usually five). The thorax has eight segments and the abdomen usually seven.

Without attempting to enumerate the orders, we may mention the Amphipoda, and illustrate them by the beach fleas and sand hoppers,

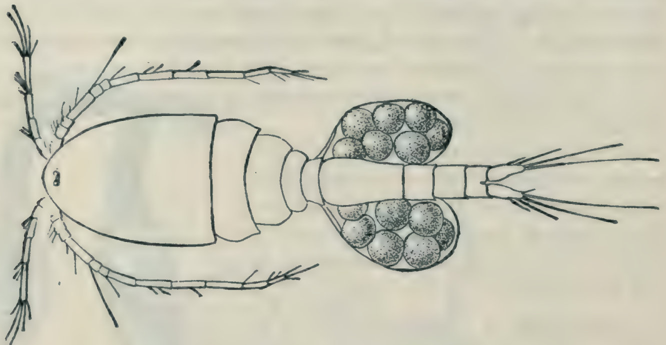


FIG. 56. WATER FLEA (CYCLOPS).
Female with egg sacs. There is a single eye with two facets.

which have a laterally compressed body, the anterior legs bearing gills, and the posterior used for jumping.

The Isopoda have a body flattened from above, and bear gills on the abdominal appendages, as in the sow bug, shown in Fig. 57.

The Decapoda, or ten-footed Crustacea, are so named from the five large pairs of thoracic appendages observed in the crayfish, which serves as an example of the group. The Decapods are sometimes further divided into the Macrura, or long-tailed forms, such as the crayfish and lobster, and the Brachyura, or short-tailed forms, such as the crabs.

FIG. 57. SOW BUG (Crustacean).

Characters of Crustacea. — 1. The crustaceans have a hard cuticle, formed by the underlying skin. The cuticle consists largely of a substance called *chitin*, which is tough and more or less elastic. The chitin becomes more or less infiltrated by carbonate of lime, and is thus made harder.

2. But the limy material is not deposited everywhere in the cuticle. Certain places are left for joints. At these places the chitin remains flexible. Hence we have a series of segments joined together, five in the head, consolidated, eight in the thorax, and usually seven in the abdomen, twenty being the typical number in the higher forms.

3. Not only is the body segmented, but normally each segment bears a pair of appendages, which are themselves segmented. The eyes are no longer regarded as appendages, but outgrowths of the head, which later become movable by means of a joint.

4. Most crustaceans have gills and lead an aquatic life. Some of the simpler forms breathe by the whole surface of the body, and a few forms which have gills live out of water, but usually in damp places. The gills remain moist, a small amount of water serving to transmit the oxygen from the air to the blood within the gills.

5. Crustacea normally possess two pairs of antennæ.

6. Most crustaceans have compound eyes.

7. Crustaceans are an active group, but, as above noticed, some are sessile, and others parasitic.

The King Crab. — The king crab, or horseshoe crab, has a body shaped somewhat like a horseshoe. A six-sided abdomen fits into a deep notch in the posterior margin of the cephalothorax, and ends in a long, tapering spine. On the cephalothorax is one pair of simple and one pair of compound eyes. The mouth is in the center of the under surface, between the bases of the legs, and a series of leaflike gills are to be found under the abdomen. The king crab is found along our Atlantic coast, often burrowing in the sand. It molts by splitting the shell along the anterior margin. The hard crust, the molting, the gills, and general mode of life would seem to ally the king crabs to the Crustacea, but later researches place them nearer the spiders. They have some points of relationship with the extinct trilobites, and are especially interesting as the only known survivors of their race.

CHARACTERISTICS OF ARTHROPODS.

1. Arthropods have an external skeleton, or *exoskeleton*.

2. This skeleton consists of a series of rings, movable upon one another, *i.e.* the skeleton is segmented.

3. Some of these rings, or segments, bear appendages that are segmented.

CLASSIFICATION OF ARTHROPODA.

ARTHROPODA.

Crustacea (Class I).	(Tracheata.)
1. Aquatic (generally) — breathe by gills.	1. Aërial — breathe by air tubes or "lungs."
2. Antennæ — 2 pairs.	2. Antennæ — 1 pair (or none).

	(Class II) *Arachnida.*	(Class III) *Myriapoda.*	(Class IV) *Insecta.*
Parts of Body.	Two { 1. Head-thorax. 2. Abdomen.	Many { 1. Head. Other rings all alike. 2. Body worm-like.	Three { 1. Head. 2. Thorax. 3. Abdomen
Legs.	4 pairs.	Many pairs.	3 pairs.
Antennæ.	None.	1 pair.	1 pair.
Jaws.	2 pairs.	2 or 3 pairs.	2 pairs.

Learn

CHAPTER VI.

BRANCH ANNULATA.

THE SEGMENTED WORMS.

Example — The Earthworm.

Habits of Earthworms. — The name "earthworm" is so appropriate that no one questions its fitness. As every one knows, the earthworm burrows through the soil, usually making the hole deep enough to reach moist earth. The first portion of the burrow is usually vertical, but deeper its course is somewhat irregular. The worms swallow the soil, and from it they derive a considerable part of their food, digesting out of it the organic matter, which is largely composed of decaying plant material. The earthworm has the advantage of utilizing as food the material which it must excavate to make its burrow. In this respect it has a decided advantage over such animals as the mole or pouched gopher, which, as they proceed, are obliged to carry out or push aside the soil without deriving any immediate benefit from it. Earthworms are nocturnal in their habits, and the fact that they are seldom seen except when dug up leads most people to suppose that they spend their whole lives beneath the soil. But this is not the case, for if one searches for them with a lantern, they may be found in summer nights, sometimes wholly out of their holes, sometimes partly out, holding fast to the sides of the burrow by the tail end, and ready to retreat at the approach of danger. If they are found crawling about in the day-

time, except after a heavy rain, it is pretty good evidence that they are diseased. Often in such cases it is found that they have been parasitized by a fly. Nearly every one must have noticed in the morning the fresh excrement, at the mouths of their burrows. These coiled "castings," as they are called, are the residue of digestion, and as the amount of nourishment in the soil is not great, and since the worm must do considerable excavating, the amount of the "castings" is necessarily considerable. In dry weather the worms dig deep, and may be several feet from the surface. But when the ground is fairly moist they often remain during the day near the surface, with one end near the end of the hole. In winter they hibernate below the reach of frost.

Form of the Earthworm. — The end that usually goes foremost is the *anterior* end, and the hinder end is the *posterior* end. When crawling on the ground the surface on which the worm rests is the *ventral* surface, and the surface uppermost is the *dorsal* surface. If the earthworm were split lengthwise in the middle line by a vertical plane, the right and left halves would be counterparts of each other, that is, the earthworm is *bilaterally symmetrical.* The earthworm is approximately cylindric, the anterior end being more pointed, and the posterior end somewhat flattened, especially on the ventral surface. The division of the body into rings, or segments, is very evident. Toward the anterior end is a region of about six segments in which the sides and dorsal portions of the segments are swollen and more or less fused together, forming a wide girdle called the *clitellum*, the function of which is to secrete the capsule in which the eggs are laid.

General Plan of Structure. — As just noted, the body of the earthworm is cylindric. At the anterior end is the mouth and

at the posterior end is the anus. These are the two ends of the digestive tube, which runs straight through the body, being, on the average, about half the diameter of the body. The body, then, consists of two tubes, the outer wall, or body wall, and the digestive tube; the outer tube, or body wall, narrowing till it joins the inner tube. Between these two tubes is a space, the body cavity, or celom. In most of the higher animals we find a similar space around the digestive tube and within the body wall. In the earthworm the body cavity is divided into many compartments by the partitions that extend between the inner and outer tubes at the constrictions, seen on the outside, between the successive segments.

The Body Wall. — This consists of two coats, each of which is made up of two or more layers. Outside is the skin, and within this the muscular coat.

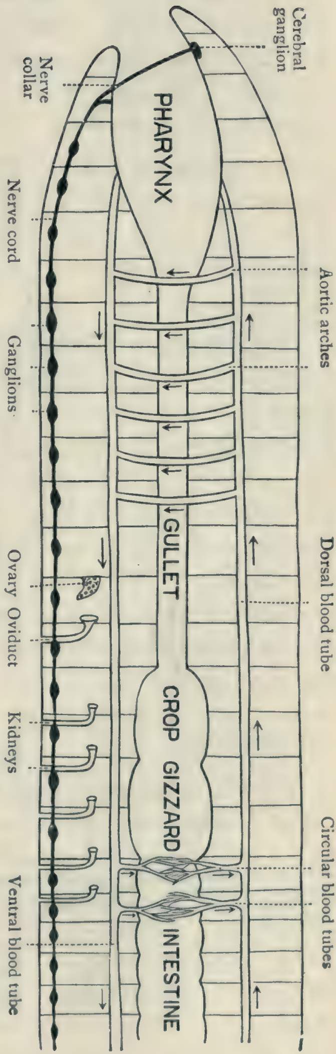


FIG. 58. STRUCTURE OF EARTHWORM, SIDE VIEW.

The Skin. — This consists of two layers. Outside is the cuticle, a thin layer, usually showing a beautiful iridescence. The cuticle often peels off in specimens that have been in alcohol. Underneath the cuticle is the epidermis (often called the hypodermis).

The Muscular Coat. — The muscular coat is very much thicker than the skin. It consists of two layers, — an outer layer of circular muscle fibers, and an inner layer of fibers running lengthwise. The inner layer is much thicker than the outer.

The Bristles. — The bristles, or *setæ*, are short, stiff, chitinous spines, in four rows along the ventral surface and lower part of the sides. They are outgrowths of the skin, and are lodged in infoldings, or pockets, of the cuticle, which are called setigerous glands. As the bristles are worn out and become useless, they are replaced by others; and in the same sac may be found bristles in various stages of development. Each row of bristles is double; and each segment, except the first and last, has four pairs of them. Special muscles are attached to the base of the sac holding the bristles, so that the bristles can be turned and held in various directions. The bristles can also be protruded and withdrawn.

How the Earthworm Crawls. — When the worm wishes to crawl forward, the spines are turned backward. Then the longitudinal muscles shorten, and the posterior end of the body is pulled forward, the whole body becoming shorter and thicker. Next the circular muscular fibers are shortened; this narrows and elongates the body; but as the spines prevent any part from being pushed backward, the result is a forward movement. By a repetition of these acts the worm effects its slow locomotion. If it wishes to

travel with the posterior end foremost, as it does occasionally, it has but to point the spines forward, and the same action of the muscles will propel it posterior end foremost. If the worm were lying on a perfectly smooth surface, on which there was no friction whatever, the shortening and lengthening of the body would avail nothing in the way of *locomotion;* it would be simply *motion.* The locomotion of the earthworm, however, is not essentially different from that of other animals, — they must all have some point of support or resistance by means of which they pro-

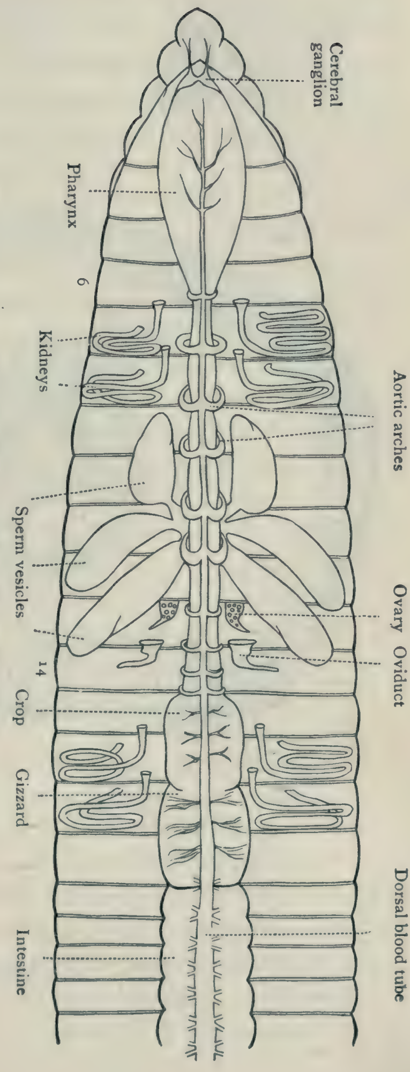


FIG. 59. STRUCTURE OF EARTHWORM.

Dorsal view, after cutting through the dorsal wall lengthwise and turning it outward.

gress. Most animals move forward by pushing backward on some more or less solid support; the earthworm pulls, rather than pushes, itself along.

What the Earthworm Eats. — Besides eating the soil, the earthworm eats leaves, both fresh and decayed, decaying

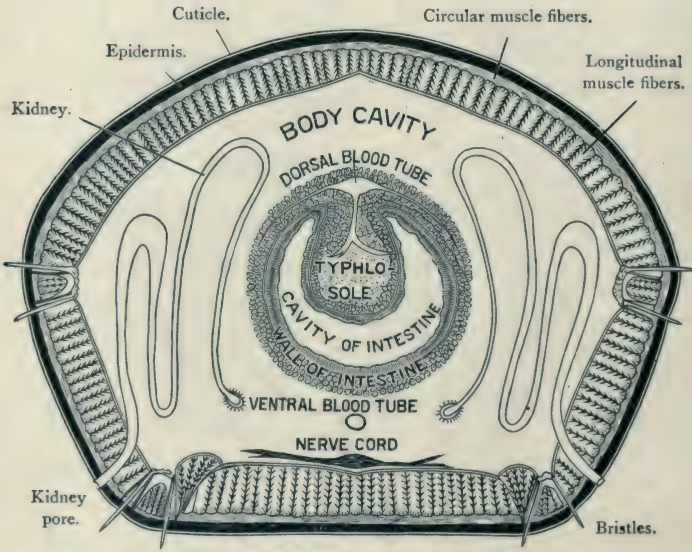


FIG. 60. CROSS SECTION OF EARTHWORM.

wood, etc. The worms drag leaves into their holes, where they are moistened by a secretion that prepares them for digestion. Earthworms eat bits of meat that are left in their way, and would seem to be almost omnivorous.

The Digestive System of the Earthworm. — The mouth is a small crescent-shaped opening on the ventral surface of the first segment. Overhanging the mouth is a small proboscis. There are no teeth, nor anything corresponding to

them. The first part of the digestive tube is the pharynx, very muscular and thick-walled. Its own muscular fibers enable it to close with considerable force. Attached to the outside of the pharynx are muscles radiating in all directions to the outside of the body wall, by means of which the pharynx can be retracted and dilated. The pharynx not only serves in swallowing, but is the worm's only organ of prehension. By means of the sucking and holding power of the pharynx the earthworm is able to drag relatively heavy leaves into the burrow. It is by the strength and various movements of the pharynx that the worm performs the work of burrowing. The pharynx extends back about six segments. Back of the pharynx is the gullet, a slender tube running to about the thirteenth or fourteenth segment. Along the sides of the gullet are the esophageal glands, whose limy secretion is supposed to aid in digestion. At about segment fifteen the gullet dilates into the large, thin-walled crop. Separated from the crop by a slight constriction is the gizzard, which extends about two segments. The walls of the gizzard are very thick and muscular, and it has a tough chitinous lining. In it, by the aid of sand, the worm grinds food, as the hen does by means of bits of gravel, thus making up for the absence of teeth. Beyond the gizzard, the intestine extends to the anus, which is a vertical slit at the posterior end. The intestine is about the same diameter throughout, except that it is constricted at each partition, and bulges out in each segment.

If a cross section of the intestine be made, it will be found that the hollow is not circular, as would naturally be expected from the external form, but is crescent-shaped, with the concave side of the crescent uppermost. This is due to a prominent ridge that projects downward from the upper inner surface of the intestine. This ridge is called

the *typhlosole*. It is richly supplied with blood tubes and serves to increase the surface for the absorption of food.

As the food passes along the digestive tube it has added to it liquids secreted by the intestinal walls, and these juices have the power to digest starchy, fatty, and proteid foods. As the food is digested it is absorbed through the intestinal walls, either into the liquid of the body cavity, or into the blood tubes that branch through the walls of the intestine, or into both of these.

The Blood. — The blood of the earthworm is red, and the red color is due to a substance called hemoglobin, as in human blood. But the color is in the liquid itself, and not in the corpuscles as in our blood. Small colorless corpuscles are present in the blood. The liquid found in the body cavity has also corpuscles, and this liquid is comparable to the lymph of higher animals. It is colorless or sometimes milky in appearance. There is a minute pore opening in the dorsal part of most of the segments.

Circulation of the Blood. — In watching the live earthworm one sees a dark red streak through the dorsal wall; this is the dorsal blood tube. It usually shows plainly a wavelike motion running from the posterior end to the anterior end. The action is due to the successive shortening of the circular muscle fibers in the wall of the blood tube, from behind forward. This sort of action is familiar to many under the name of peristaltic action, such as takes place in the intestines of most animals. By this action the blood is continually driven forward in this blood tube. A similar blood tube is to be found under the intestine, the ventral blood tube. In it, by the same means, the blood is sent backward. These are the principal longitudinal blood tubes, but there are three small tubes close to the nerve cord. In the region of the gullet

are several, usually five, branches that connect the dorsal and ventral blood tubes; they arch around the gullet on each side, hence are designated the "aortic arches"; in some forms they have a series of enlargements, presenting a necklace-like appearance. These enlargements contract and dilate rhythmically, hence they are sometimes called "hearts," but they probably have no greater share in the work of propelling the blood than the other blood tubes. Connected with these main blood tubes are branches by which blood is supplied to the body walls, to the walls of the digestive tube, to the partitions between the segments, to the kidneys, and all the organs of the body.

One earthworm common in the central states has two dorsal blood tubes (hence the name, Diplocardia). This is a large worm whose girdle extends from the 13th to the 18th segment. It has two gizzards.

How the Earthworm Breathes.—The earthworm breathes by means of the skin, there being no special organs of respiration. The body wall is richly supplied with a fine network of blood tubes. These are separated from the external air by a thin membrane only. This thin and delicate covering is always moist, and through it an interchange is continually taking place between the blood within and the air without; oxygen is being absorbed into the blood, while carbon dioxid and other waste matters are passing in the opposite direction. The worm cannot live long in a warm, dry air, for, when the skin cannot be kept moist, respiration is stopped and the worm is suffocated. They can endure immersion in water for some time, but it seems injurious to them. They often are found crawling about in large numbers after a heavy rain.

The Excretory System of the Earthworm.—Part of the waste matter, the carbon dioxid, is thrown off by the skin,

as we have just noted. There is also in each segment (except a few at the two ends of the body) a pair of simple kidneys. Each kidney is a tube opening freely into the body cavity at its inner end, while the other end opens to the outside through a small aperture in the body wall below (or sometimes above) the upper row of bristles. This long tubular kidney is thrown into loops, and there is considerable variation in its diameter at different points. Each tube begins as an open funnel which is lined with cilia. The oddest fact about these tubes is that each kidney begins in one segment and ends in another; the funnel is in the back part of the segment and the tube from it soon passes through the partition behind it, the bulk of the tube lying in the segment posterior to the one in which it began. These tubes absorb waste matter from the liquid of the body cavity, and convey it to the outside.

The Nervous System of the Earthworm. — This is a chain of nerve centers or ganglions along the ventral part of the body cavity, lying under the intestine. In each segment is a ganglion, and these are connected by a nerve cord running lengthwise. Though apparently single, the nerve cord and chain are really double, the two ganglions and cords being so closely applied and fused that they appear as one. The shortness of the segments brings the successive ganglions so near together that they are not very distinct. In the anterior region the double nature of the cord is apparent. Under the anterior part of the pharynx the two strands of the cord separate, one passing up on each side of the pharynx to a large ganglion, the two ganglions lying closely side by side, forming the "brain." Thus a ring is formed around the pharynx, which is called the "nerve ring" or "esophageal collar." From all the ganglions nerves proceed to the surrounding organs.

The Senses of the Earthworm. — The sense of touch is undoubtedly most fully developed, and on this sense the worm largely depends for its knowledge of the outer world.

The sense of taste exists, and probably smell also, for the earthworm exercises choice of various foods offered it, as shown in many experiments made by Darwin.

The earthworm can distinguish between light and darkness, as evidenced by the fact that it retires to its burrow at the approach of day. When a strong light is flashed upon the anterior end of the earthworm, it retreats. The posterior end is also sensitive to light. But there is no reason for supposing that the worm sees objects with any distinctness, as do animals with well-developed eyes. There is no evidence of a sense of hearing.

Development of the Earthworm. — The ovaries are small and close to the ventral surface, usually in the thirteenth segment. The oviducts open on the fourteenth segment. The eggs are inclosed in capsules of albuminous material formed by the girdle, or clitellum. In May and June the capsules containing the eggs of one species are deposited in the earth under logs and stones, or especially in, or under, manure heaps. The little worms are about an inch long when hatched.

Enemies of the Earthworm. — The principal enemies of the earthworm are moles and birds. To escape the latter the worms usually retire into their holes at the approach of day, often plugging the mouth of the hole with pebbles. If they are too slow in hiding, or neglect to shut the door, the sharp eyes of the bird may discover them. The early bird gets the late worm.

Distribution of Earthworms. — Earthworms are very widely distributed, being found nearly all over the world, even in isolated islands of the ocean. There are many species, but they are all much alike in most features which are essential for our present knowledge.

Effect of Earthworms on the Soil. — Darwin says that in all regions where there is found a smooth expanse of vegetable mold, which is the substance of all black soils, this mold has passed and will pass again, every few years, through the bodies of earthworms. Before the observations and experiments of Darwin the world hardly dreamed what an important part earthworms have played in making the soil what it is, but some previous observers had an inkling of it. The quality of the soil is altered by the digestive process. It is worked over, and the deeper layers are brought to and deposited upon the surface. This inversion of the soil is essentially the same as that of plowing, so, as Thomson says, earthworms were plowers before the plow. The holes also aid circulation of air and water in the soil. To get a clear idea of the effects of these worms on the soil, the student should read Darwin's *Vegetable Mould and Earthworms*.

Number of Earthworms and Extent of their Work. — Darwin estimated that in the tillable soil of England there were, on the average, over fifty thousand earthworms to the acre; that they bring up eighteen tons of soil to the acre; that they cover the surface at the rate of an inch in five years; and that thus in long ages they have buried large rocks and ancient buildings. And his conclusion is that "it may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized animals." In the United States earthworms are not so numerous.

Harm done by Earthworms. — Earthworms do some harm by eating tender seedlings and delicate roots, but this is trifling in amount as compared with the very great aid they render to agriculture.

Repetition of Parts. — If a person had grown up without having seen an earthworm, at first sight of one he would probably be impressed with its sameness of structure, nearly all the rings or segments having the same general appearance. Dissection shows that the internal structure is not so very different, the anterior portion having somewhat of a variety in the development of the parts of the digestive, circulatory, and reproductive organs. Back of the middle of the body there is no segment which adds anything new in function to the body, each segment being simply a repetition of what precedes. As a rule, multiplicity of parts, without corresponding variety of structure and function, marks an animal as low in rank.

Recovery after Mutilation. — When an earthworm is cut in two in the middle, the anterior end probably lives in most cases, as it has all the

kinds of parts or organs that the earthworm possesses; it has simply lost a part of the intestine, nerve cord, blood tubes, etc., but not all of any one set of organs.

Color of the Earthworm. — The color of the earthworm is largely due to the color of the blood and to the matter contained within the digestive tube. But besides this, the dorsal surface is darker than the ventral, as is the case with most animals.

The Sandworm. — One of the commonest of the sea worms (Nereis) is known as the sandworm or clam worm. It is cylindric, bluish green, and from six inches to a foot

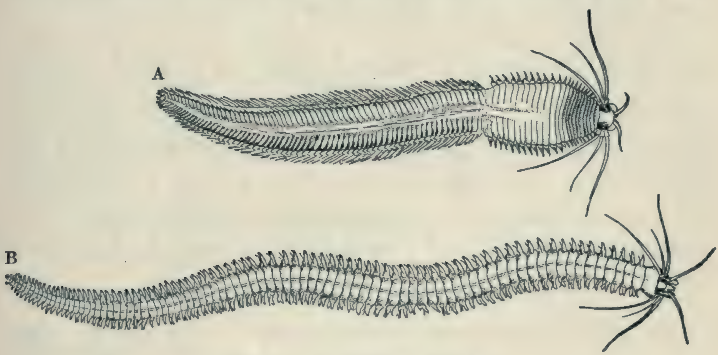


FIG. 61. A MARINE WORM.
A, appearance at breeding season, and *B*, at other times.
From Jordan and Heath's *Animal Forms*.

long. It is abundant along the Atlantic coast, and is an excellent type to study, especially when the earthworm cannot be readily obtained. One can usually find them at low tide along the sandy or muddy beaches. They make burrows in the sand, but they are to be found at night, swimming freely, especially during the breeding season.

One of the first points of difference between Nereis and the earthworm is that Nereis has a distinct head. On the top of the head are two pairs of eyes. There are also several pairs of antennæ and a pair of palps. Back of the

head the segments are all alike. On each side of every segment are muscular projections, called parapodia; each parapodium has several lobes, and these lobes are provided with bundles of bristles, capable of extension and retraction, and also of being turned in different directions, as in the case of the bristles of the earthworm. By means of the parapodia and bristles the sandworm can crawl, and it also swims by the same means. In the middle region of the body the parapodia serve as gills, and the blood flowing in the thin projections gives them a red color.

The internal structure, in the main, is very much like that of the earthworm. The pharynx is muscular, and is everted in seizing food; but the sandworm has a pair of strong, hard, horny teeth, with which it can grasp and kill other worms and small animals that it eats. It also consumes vegetable food. It is itself a favorite morsel for many kinds of fish, and hence is much used by fishermen as bait.

The Leech. — Leeches are usually flattened. They have no spines nor appendages of any sort. There are from one to five pairs of eyes on the anterior segments. The body appears to have many segments, but dissection shows that many of these grooves are mere external wrinkles, there being but one partition for from three to five of the constrictions. There is always a sucker at the posterior end, and in some leeches one at the anterior end also, as in the well-known medical leech of Europe, formerly much used in bloodletting. The mouth has three radiating jaws, each bearing many fine teeth on its edge. The jaws are acted on by muscles which work them back and forth like a semicircular saw. The blood thus obtained is sucked into a crop, which makes up the principal part of the digestive tube. The crop has several pairs of side pouches in which the blood is stored, and it is said that the leech can take enough at one meal to last a year. The blood does not coagulate in the crop, and this is said to be due to the action of the saliva. Digestion is accomplished in the narrow stomach posterior to the crop. A short intestine succeeds the stomach. Leeches have three

modes of locomotion: (*a*) they creep along with a gliding movement like a snail; (*b*) they swim by a graceful undulatory motion; (*c*) they travel by a "looping" action, somewhat as in "measuring worms," holding on alternately by the anterior and posterior suckers, some leeches thus progressing actively.

Other Annulate Worms. — There are many annulate worms, mostly marine. Some are free-swimming, while others live in tubes which they form of mud, sand, or limestone. Many of them have beautiful, feathery gills, sometimes distributed along the body, but in the tube-inhabiting forms more frequently at the head end. Many sea worms are phosphorescent, emitting a vivid green light.

CHARACTERISTICS OF ANNULATA.

1. The body is bilaterally symmetrical; there are also distinct anterior and posterior ends, and dorsal and ventral surfaces.
2. The body is segmented (except Gephyrea).
3. There is a distinct body cavity, divided by partitions into as many compartments as there are segments.
4. There is a well-developed blood-tube system for the circulation of blood.
5. A nervous system is present, consisting of cerebral ganglions, esophageal collar, and ventral nerve cord.
6. There are tubular kidneys in each segment.

CLASSES OF ANNULATA.

Annulata.	Class 1. Chætopoda (bristle-footed).	1. Oligochæta (few bristles — earthworm).
		2. Polychæta (many bristles — Nereis).
	Class 2. Gephyrea.	
	Class 3. Archi-annelida.	
	Class 4. Hirudinea — the leeches.	

CHAPTER VII.

BRANCH MOLLUSCA.

THE branch Mollusca includes clams, oysters, scallops, snails, slugs, squids, and cuttlefishes. The large majority of mollusks have shells. The shells have always been objects of great interest on account of their beauty of color, delicacy of texture, and variety of form. Their durability and the ease with which a collection may be made and kept have further contributed to making the mollusks a favorite subject of study.

CLASS PELECYPODA.

Example. — The Fresh-water Clam.

Where Clams Live. — Clams live in creeks and ponds, lakes and rivers. They are usually less abundant in the smaller streams, as these may become dry in midsummer. The natural position of the clam is shown in Fig. 64.

External Features of the Clam. — The clam shell is composed of two equal valves, fastened together at the dorsal margin by a tough, elastic membrane, the hinge ligament. Somewhat nearer the anterior than the posterior end is a raised point close to the dorsal margin; this is the umbo; it is frequently more or less worn or broken away, which is not surprising, as it is the oldest part of the shell and is subject to friction as the clam plows along through the sand. Around this are the concentric lines of growth, running parallel to the ventral margin. Different species

of clams are distinguished by the size and shape of the shell, the relative proportions of the parts, the color markings, smoothness or roughness of the shell, the thickness of the shell, and by the hinge teeth on the interior.

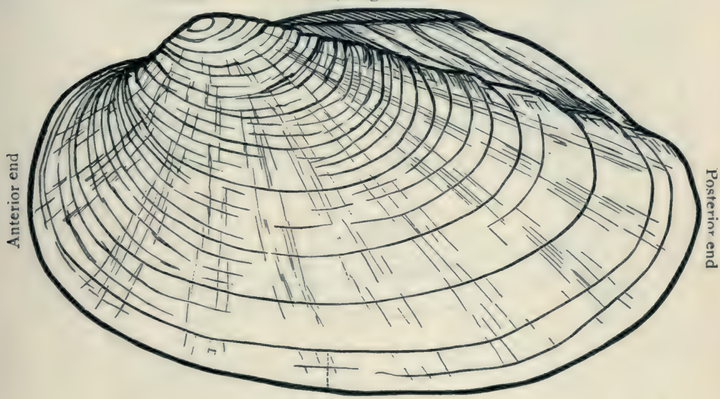


FIG. 62. EXTERNAL FEATURES OF A CLAM SHELL.
Outside of left valve.

The Inside of the Clam Shell. — After the soft parts are removed, the following internal markings are usually plainly seen. The scars are the places of attachment of the muscles, of which the most notable are the anterior and posterior adductor muscle scars. Just below and posterior to the anterior adductor scar is the scar of the protractor of the foot. Above the anterior adductor scar is the scar of the anterior retractor of the foot. Just above and anterior to the posterior adductor scar is the scar of the posterior retractor of the foot. There are also a few small scars of muscles in the dorsal regions. In removing the body of

the clam, it will be found that the mantle has several muscular attachments. Running parallel to and not far from the ventral margin is the mantle line, the line of attachment of the inner edge of the muscular portion of the mantle.

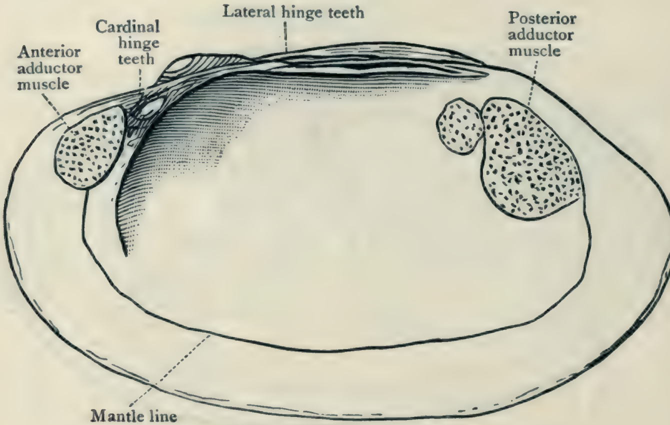


FIG. 63. INSIDE OF RIGHT VALVE OF CLAM SHELL.

The Hinge Teeth. — In most species of fresh-water clams there are interlocking projections near the dorsal margin of the valves. Near the anterior adductor are strong, toothlike projections, the anterior, or cardinal, hinge teeth. Parallel to the dorsal margin, near the hinge ligament, are long ridges, the lateral or hinge teeth; there are usually two of these on one valve and one on the other, which fit together when the shell is closed. These teeth aid in keeping the shell shut.

The Natural Position of the Clam. — The ventral margin is imbedded in the mud or sand, the anterior end usually considerably deeper than the posterior. This position brings the siphon openings above the mud; but at

times the whole shell is buried in the soil; this seems to be the case more often in the winter, when the clam is less active, or after freshets which cover the clams with mud.

The Clam at Home. — By watching the clam in its natural habitat the position, as above described, may be observed. It may be seen that the shell is slightly agape; that a soft membrane protrudes from the opened edges of the shell; that at the posterior end are two elliptical openings. It may be proved that a current of water is entering one of these openings and issuing from the other. If the borders

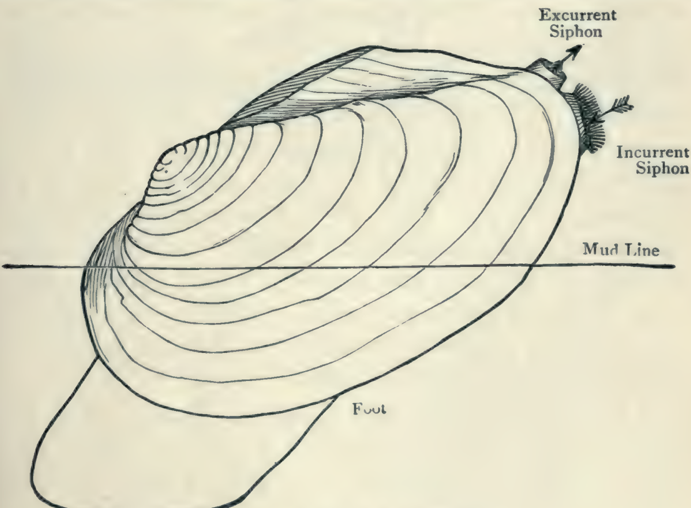


FIG. 64. CLAM IN NATURAL POSITION.
With foot and siphons extended.

of these openings are touched, the soft membrane forming the margins of the openings is withdrawn into the shell, and the shell is tightly closed. If a clam, previously undisturbed, be quickly pulled out of the mud, a soft, fleshy

projection, the foot, is found extending from the anterior ventral margin; but this will be at once, though not rapidly, retracted, and the shell securely shut.

The Enemies of the Clam. — The question naturally arises, "Why does the clam need such a strong protective covering?" The working parts of the body are soft, the Latin word *mollis* giving the name to the whole branch — Mollusca. Such a soft-bodied animal would naturally be the prey of carnivorous animals. And further, since the clam is slow in movement and has few and poorly developed senses by means of which to become aware of the presence of enemies, it is not surprising that it should be thus securely protected. Among his most dangerous foes are the raccoon, otter, mink, and muskrat, and probably other mammals that frequent the water or prowl along the banks of our streams. Muskrats open the shell by first gnawing off the hinge, after which it is comparatively easy to open the shell. Against its enemies the clam has, apparently, but the one means of defense, namely, to shut the shell as strongly as possible and to keep it shut till the coast is clear. Man, whether gathering specimens for study, seeking pearls, or gathering the shells for buttons, is to be reckoned among the clam's enemies.

How the Clam opens and shuts its Shell. — Two large cylindrical muscles pass directly across the body of the clam, connecting the two valves. One of these muscles is at the anterior end, the anterior adductor muscle, and the other, the posterior adductor muscle, is at the posterior end. The ends of these muscles are strongly attached to the inside of the shell. When they shorten they bring the two valves together and hold them with great force.

For an inch or so along the dorsal margin the two valves are held together by the elastic hinge ligament, which is

merely an uncalcified portion of the shell. When the muscles pull the valves together, this ligament is stretched. Consequently, as soon as the adductor muscles relax, the elasticity of the hinge ligament opens the shell. It will be observed that the shell is shut by muscular effort, whereas it is opened by the mechanical action of a spring, which consists of practically dead tissue. It requires no effort to

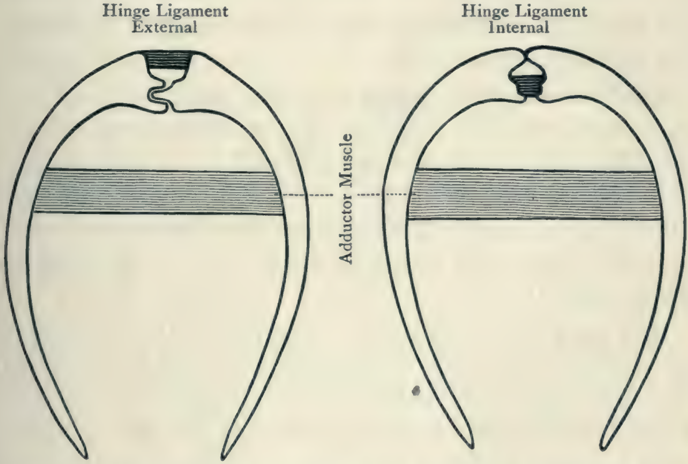


FIG. 65. MECHANISM FOR OPENING AND SHUTTING A CLAM SHELL.

keep the shell open. As the shell is partially open most of the time, the economy of this arrangement is apparent. Why would it not do as well to have the shell opened by muscular action and closed by a spring? In some bivalve mollusks the hinge ligament is internal, so that when the shell is shut the ligament is compressed, instead of stretched, as in these clams. Then, when the muscles relax, the shell is opened by the expansive elasticity of the ligament. The general principle is the same, but is carried out in a different way. See Fig. 65.

Why the Clam opens and shuts its Shell. — It is only by opening the shell that the clam is able to place itself in communication with the outside world. The opening allows the foot and siphons to be protruded. When disturbed, the clam withdraws the foot and the siphons, and completely closes the shell, and usually remains in this condition until the disturbance ceases. The muscles are of the slow-acting, non-striped kind, and can remain shortened a long time; but they evidently get tired, and after a while they relax, and the shell gapes open.

The Location of the Siphons. — Since the clam pulls itself forward by the foot, which it imbeds in the mud, the foot naturally extends forward and downward. As a good share of the ventral part of the shell is below the level of the sand or mud, the only available place to take in clear, fresh water is at the upper and posterior border. And here we find the siphons.

How the Clam Progresses. — The foot is slowly extended forward and downward into the mud. When it has become well imbedded in the mud, if the clam wishes to move forward, it shortens the muscles of the foot and body, and thus pulls forward the body, shell and all. Then another interval must elapse until the foot is again anchored before another move can be made. In this way the clam slowly plows its way along, leaving a distinct furrow by which it may be traced in clear water. The protruding of the foot is a slow process, while the act of pulling forward is of comparatively short duration. It is stated that the extension of the foot is mainly due to an inflow of blood which is kept from returning by a tightening of the sphincter muscles around the veins. At any rate, the foot is often found dilated toward the extremity, which plainly increases its efficiency as an anchor.

Extent of the Clam's Locomotion. — The clam does not travel far. Since it brings its food in by the currents of water which it creates, it does not have to move about for food. When the water gets low, as in most creeks in the summer time, the clam apparently seeks the deeper water. The question naturally arises, "How does the clam become aware of this change, and how does it know in what direction to go?"

The Clam's Muscles and their Functions. — There are five chief muscles: —

1. Anterior adductor. } Close the shell. See Figs. 63
2. Posterior adductor. } and 65.
3. Protractor — pulls the foot and body forward and downward.
4. Anterior retractor — pulls foot and body upward and backward.
5. Posterior retractor — pulls foot and body upward and backward.

When the foot is imbedded in the sand or mud, the shortening of the retractors, whose fibers spread over the body and foot, pull the shell forward instead of retracting the foot.

Structure of the Clam Shell. — If a shell is roasted thoroughly, its structure may more easily be learned. The first fact to be noted is that the shell consists of layers; the next, that these layers are in two sets, the dividing plane between which starts from the mantle line and extends toward the umbo. The shell is an outgrowth of the outer layer, or epidermis, of the mantle. But the layers of the shell made by the part of the mantle outside of the mantle line are not directly continuous with the layers formed by that part of the mantle which is dorsal to the mantle line. The mantle line is really a row of small muscle scars where

the muscular border of the mantle is attached to the shell. The edge of the mantle, it was observed, is attached to the edge of the shell. The outermost layer of the shell, the

FIG. 66. STRUCTURE OF CLAM SHELL.
Cross-section.

periostracum, is formed by the edge of the mantle, and is horny in composition. Inside this is the prismatic layer, and innermost is the laminated pearly layer.

Growth of the Clam Shell. — The successive concentric lines of growth seen on the outside of the shell mark the growth, each line of growth having once been the ventral edge of the shell. The layers are formed by the mantle, and each new layer is a little wider and longer than the one preceding, and outside of it. The muscles grow and gradually move outward, hence the muscle scar continually widens, forming a triangle. But as the muscles move on, the scar of former years is covered by the new layers formed by the mantle.

Uses of the Clam Shell. — The fresh-water clams are little used as food, but their shells are used largely in making buttons. This is an industry of considerable extent along the Mississippi River and some of its tributaries.

Respiration in the Clam. — The current of water which we saw entering and leaving the clam brings oxygen as well

as food. The blood circulates in the walls of the gills, and thus the water current and the blood current are brought very close to each other. Oxygen passes from the water into the blood; and from the blood, carbon dioxid and other waste matters pass into the water through the thin layer of the wall of the gill surrounding the blood tubes. There is also an active circulation of blood in the mantle, and a considerable share of the work of respiration is undoubtedly accomplished here.

The Structure of the Gills. — Each gill has the appearance of a thin, single-layered membrane; but in reality each gill

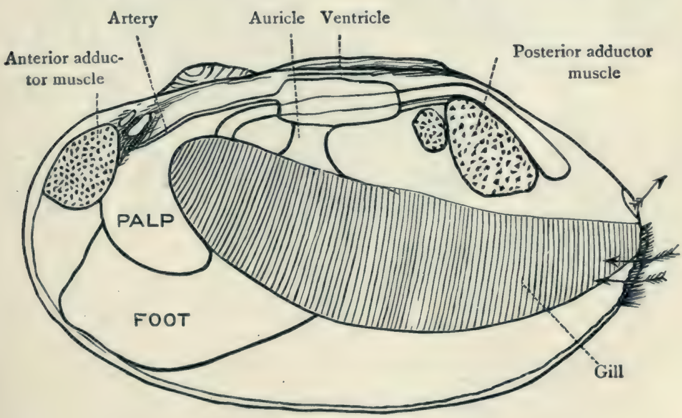


FIG. 67. BODY OF CLAM.
Left valve removed.

is double walled, and a cross section is like a letter V. Each gill is a long, narrow, V-shaped pocket or trough, though divided into many compartments by cross partitions. The two gills of each side are united so as to form, in cross section, a W, the upper margin of the outer wall of the outer gill being attached to the mantle, the upper edge of

the inner wall of the outer gill joining the upper edge of the outer wall of the inner gill, while the upper edge of the inner wall of the inner gill is sometimes attached to the body or sometimes free. Back of the body the upper edges of the inner gills of the two sides unite with each other, thus separating the lower, or gill, cavity, into which the water first

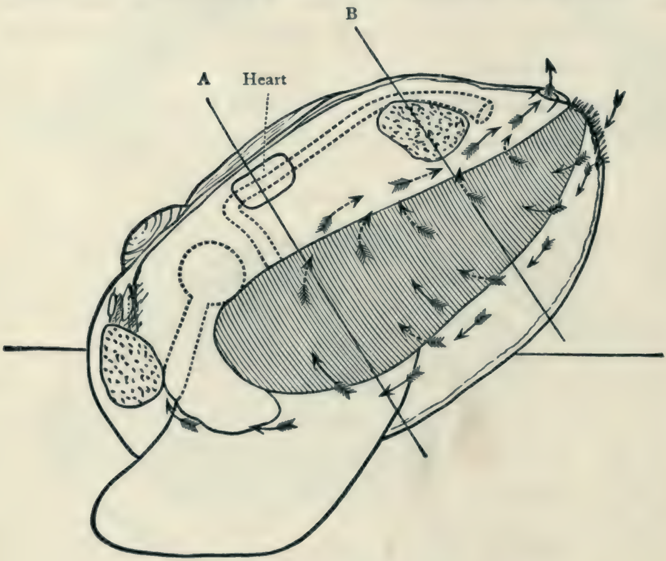
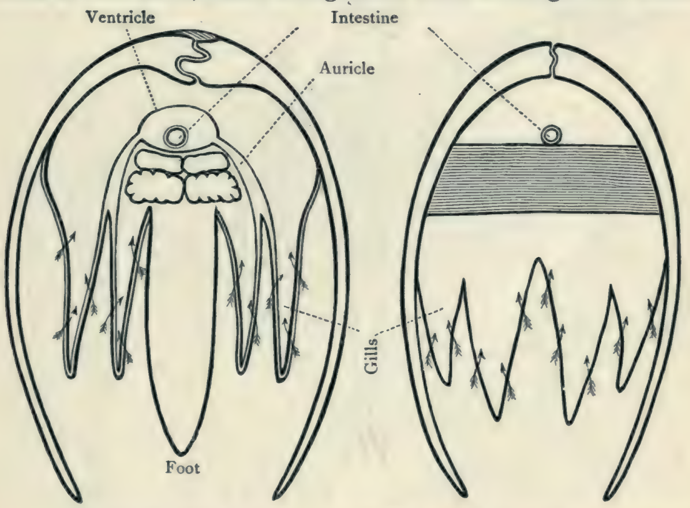


FIG. 68. CLAM, SIDE VIEW.
Water currents to the mouth and through the gills.

enters, through the lower incurrent siphon, from the upper, or cloacal, chamber, from which the water passes out. The question presents itself, "How does the water pass from the one cavity into the other?"

The sides of the gills are perforated, so much so that they are compared to a sieve or trelliswork. The vibrations of the myriads of cilia with which the gills are covered drive

the water that lies outside of the gill through these openings into the space within the gill. The water then passes up through the open top of the gill into the cloacal chamber, and back out of the excurrent siphon. The four gills are so many narrow, V-shaped troughs with their sides full of holes. Instead of filling at the top and leaking out at the holes in the sides, these troughs are filled through the holes



Cross section through heart. Section at *A*. Cross section through posterior adductor muscles. Section at *B*.

FIG. 69. CLAM.

Water currents through the gills. Compare with Figs. 68 and 71.

in the sides, and overflow above, — only the water cannot run down the sides of the trough, but must pass back and out through the upper siphon. (Figs. 68, 69, and 70.)

The Food of the Clam, and how Obtained. — The clam lives on microscopic plants and animals and on minute particles of organic matter. This material is supplied by the current of water which is continually passing into the lower

and out of the upper siphon. The current is produced by the vibration of the cilia which cover the outside of the gills and the inner surface of the mantle. The entering current passes forward around the body and gills. The palps are also ciliated; and between the two palps of each side the minute particles are caught and passed on into the mouth,

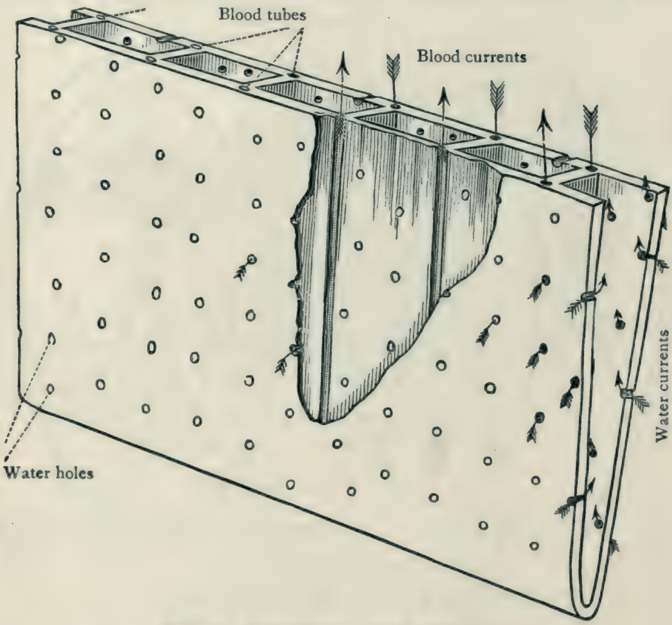


FIG. 70. STRUCTURE OF CLAM'S GILL.

whose upper lip is formed by a continuation of the two outer palps meeting across the middle line, the two inner palps similarly forming a lower lip.

The Digestive System of the Clam. — The mouth is just back of the anterior adductor muscle. A short, wide gullet extends upward and backward to the large spherical

stomach. On each side of the stomach is a large, greenish, digestive gland, often called the liver, whose secretion passes into the stomach. From the stomach the intestine passes downward and backward, making one or two coils in the abdomen and foot, then passes upward back of the stomach, near the dorsal margin; it then turns posteriorly, parallel to the dorsal margin, passes through the ventricle

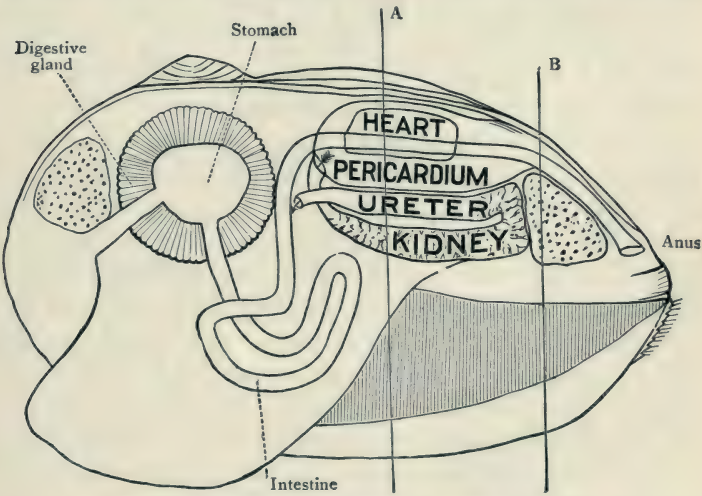


FIG. 71. DIGESTIVE AND EXCRETORY ORGANS OF A CLAM.

of the heart, over the posterior adductor muscle, just back of which it ends, thus discharging the refuse of digestion where the outgoing current of water will catch it and sweep it out of the body through the dorsal siphon. The digestive tube is hard to trace in a fresh specimen, less difficult in one which has been boiled or hardened in alcohol. The whole tube may be injected with a colored starch injection and thus readily followed. In the fall the intestine is often found to contain a cylindrical body of

clear material having the consistency of a gumdrop. This is the "crystalline rod," and is thought by some to be a store of food material. Others regard it as a secretion to protect the lining of the intestine from injury.

The Circulatory System of the Clam. — From the gills and mantle of each side the blood passes up into the corresponding auricle (Figs. 67 and 69). The auricles are wide at the base, where they arise from the upper margins of the gills, but narrow as they approach the ventricle, so that the lateral view gives a triangular appearance. The auricles are thin-walled, delicate structures. They open into the sides of the median ventricle. From the ventricle arise two arteries, one carrying blood forward above the intestine, the other extending backward beneath the intestine (Fig. 67). After leaving the arteries, the blood passes into irregular and ill-defined channels, supplying all parts except the shell. The blood collects in a caval vein under the floor of the pericardium, then passes through the kidneys, and to the gills once more. In the gills and mantle the blood loses carbon dioxid and gains oxygen. As it passes through the kidneys it loses nitrogenous waste matter, and from the digestive tube it absorbs new food material for the support of the life processes.

The Kidneys. — The kidneys are ill-defined, dark-colored organs, lying just beneath the floor of the pericardium and in front of the posterior adductor muscle. Each kidney consists of a tube doubled on itself, the bend being near the adductor muscle. One end of the tube communicates with the bottom of the anterior part of the pericardium, the other end opens on the side of the abdomen, near the upper edge of the inner wall of the inner gill, and above the tip of the corresponding palp. Here the excretion is poured out, and is carried away by the water current.

Nervous System of the Clam. — There are three pairs of ganglions, which are connected by nerve trunks, called commissures: —

1. The cerebral ganglions, one on each side of the mouth, just above the outer palp of each side; these are connected by a nerve cord which passes over the gullet.

2. The two pedal ganglions, lying closely side by side, deeply imbedded in muscle, near the middle of the foot. Each of these is connected with the cerebro-pleural ganglion of its side.

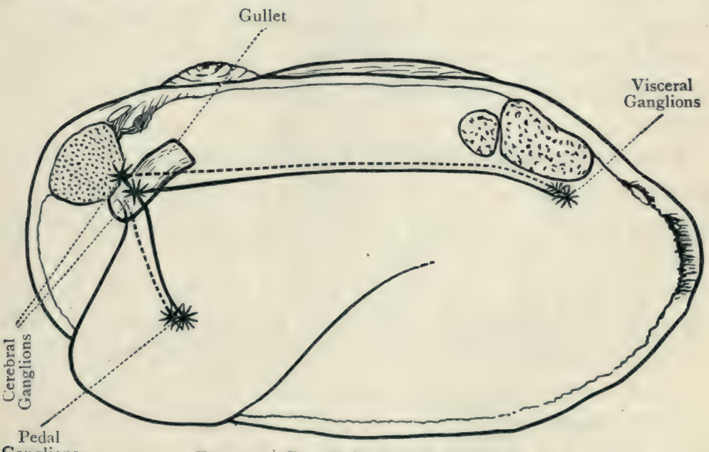


FIG. 72. CLAM, NERVOUS SYSTEM.

3. On the under surface of the posterior adductor are the two visceral ganglions, apparently forming one double ganglion. These ganglions are much easier to find than the others. Each of these is connected with the cerebral ganglion of its side by a nerve cord, which runs along in the dorsal part of the body for a good share of its length. From all of these ganglions nerves extend to supply the adjacent regions.

The Sense Organs. — The sense of touch is preëminent. This sense is best developed in the palps, along the margin of the mantle, especially that part of it which forms the borders of the siphons, and in the foot. There is no sense of sight, but the tentacles around the siphons seem somewhat sensitive to light. On a nerve near the pedal ganglion is the so-called "ear sac," of doubtful use. At the base of the gills is an organ sometimes called the "smelling patch," which, perhaps, has the office of testing the quality of the water. The sense of taste is doubtful, though it is probable that there is some discrimination as to what should be taken as food. The clam is sensitive to vibrations communicated either through the soil or the water.

The Reproductive Organs. — These are diffuse glands enveloping the coils of the intestine in the abdomen. The glands in the two sexes (ovaries and spermaries) are so similar that it usually requires microscopic examination to distinguish them. The ducts, both in the male and female, open on the side of the body near the opening of the duct from the kidneys. The eggs, when mature, pass out of the duct and lodge in the gills (more often the outer gills) of the female. They are fertilized by the sperms, which have been set free in the water and are drawn in by the same current that brings the food particles. The males and females may sometimes be distinguished by the greater convexity of the shell in the female, the valves being more bulging to accommodate the accumulation of eggs and young clams in the outer gill.

Development of the Clam. — The young usually develop during the fall and winter. When liberated, the young clams are called Glochidia. They are of different shape from the adult, being ovate, with the hinge at the wider

end. There is but one adductor muscle; the foot is yet undeveloped, but from the foot region project long threads, the "byssus," by which it becomes attached. At the tip of each valve there is an incurved hook by which the little clam usually catches hold of the fin or gill of a fish, whereby it is protected from enemies and kept in fresh water. Soon after it thus becomes attached it is covered by a growth of the skin (a diseased growth) which still

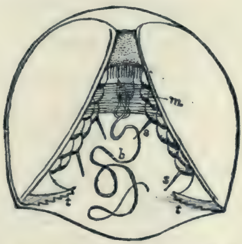


FIG. 73. YOUNG CLAM, STILL WITHIN THE EGG MEMBRANE.
m, adductor muscle; *t*, hooks by which it attaches itself to the gills or fins of fishes; *b*, byssus; *s*, sense organs.

further protects the parasite. When sufficiently mature, the young clam drops off, soon becomes like the adult in form, and shifts for itself.

Salt-water Clams. — Although several kinds of marine clams are used as food, there are two that are more largely eaten in this country. One is *Venus mercenaria*, found from Texas to Cape Cod, but rare north of that point; the other *Mya arenaria*, found generally along the coasts of the Eastern states, but rather distinctively more Northern than the other. So when Massachusetts people speak of clams they mean the Mya, commonly designated elsewhere as the "soft clam," "soft-shelled clam," "long-necked clam," or "long clam." Whereas, when New Yorkers mention clams, without any qualifying adjective, they have

in mind *Venus mercenaria*, which, farther north, and away from the coast, would be designated as the "hard clam," 'round clam," or "quahog." Both are frequently found in the markets inland.

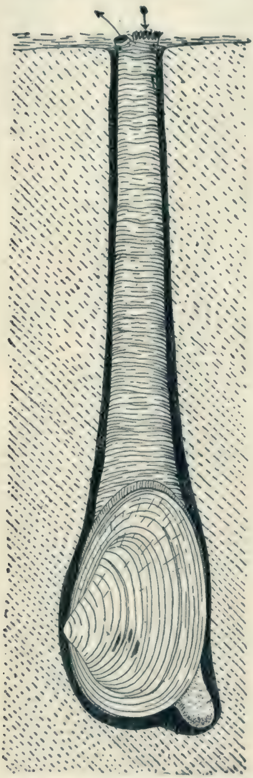


FIG. 74. LONG CLAM, BURIED IN THE MUD.

The arrows show the currents in the siphons.

From Kingsley's *Zoölogy*.

The Soft-shell Clam. — This clam lives in a vertical burrow with the anterior end down. Instead of having short siphons like the fresh water clam, the posterior margins of the mantle lobes are extended and grown together to form a long double tube, which reaches to the surface of the sand or mud, the body being sometimes a foot from the surface. The two mantle lobes are united along their entire edges, except at the two siphon apertures and an anterior opening, for the projection of the foot. The ventral channel is the incurrent and the smaller dorsal one the excurrent. As in the clam we have studied, the incurrent siphon has a fringed margin and is very sensitive. The border is also dark colored, so that it is not readily seen, and if disturbed it is withdrawn into the hole. At low tide the tube is generally so retracted. At this time clams are hunted and dug up.

As the clam grows, it deepens and widens its burrow. The foot is small, and the old clam, dug up and left on the surface, has difficulty in making a new

burrow. The internal structure is essentially the same as in the fresh-water clam. To accommodate the long siphon tube when it is retracted, there is a deep indentation of the mantle line in the posterior region. The shell of Mya cannot be snugly closed, there being a gap both anteriorly and posteriorly. Probably this may be accounted for by the more protected position and the need of having the siphon

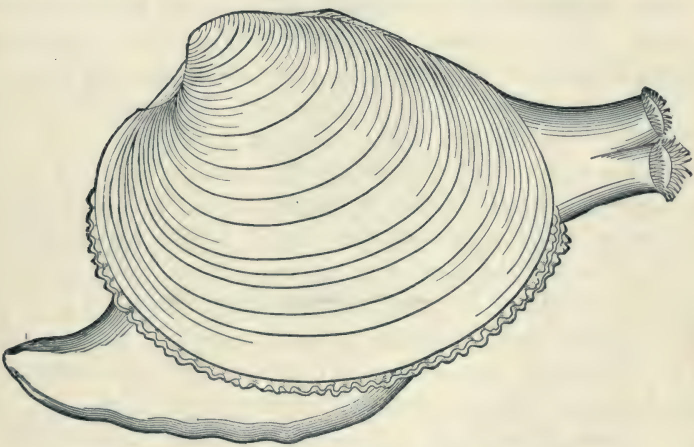


FIG. 75. HARD CLAM; ROUND CLAM; QUAHOG.
With foot, siphons, and edge of mantle extended.

tube extended most of the time. The siphon tube, with its black tip, is commonly called the "head," but this clam is as headless as its fresh-water relative.

The Hard Clam. — The hard clam, or quahog, is also an important sea-coast food, especially where the soft clam is not obtainable. It is oval, with a thick shell. It burrows but a short distance, hence the siphons are not long, and the two tubes are partly separated. The foot is well developed, and the clam crawls more or less like the fresh-

water clam. These clams may be picked up at low tide, but are ordinarily taken by means of long rakes or tongs. The smaller or medium-sized ones are preferred. The border of the inner surface of the shell is usually purplish, and this part was made into the beads which constituted the more valuable purple wampum of the Indians of New England.

The Oyster. — One essential difference between the oyster and the clam is that the oyster is stationary, being firmly attached by one valve to some solid object, a rock, or another oyster so attached. The oyster lies on the left side, and the lower valve is much more concave than the upper, which is nearly flat, serving as a lid. As the oyster does not travel, it needs no foot and has none, hence is less tough than the clam. The hinge is at the pointed end of the shell, and the two mantle lobes are free from each other, except near the hinge. There are no siphons, the water entering all along the more curved border of the shell and passing out on the straighter side near the larger end of the shell. The water is propelled by cilia and passes through the gills as in the clam. There is but one adductor muscle.

Development of the Oyster. — The eggs and young are not carried nor protected as in the clam, but the eggs are fertilized after being set free in the water. The egg becomes many-celled by the growth and repeated division of the one cell which constituted the egg. This becomes ciliated and swims by means of these cilia. After a few days of this free swimming life, during which time the shell and other organs are gradually developing, the little oyster attaches itself by its left valve to some submerged object, to which it becomes firmly cemented by the deposit of limy material which makes the hard part of the shell.

Comparison of Clam and Oyster. — It will be noticed that the hinge in the oyster is at one end of the shell. This end corresponds to the anterior end of the clam. The oyster shell can open but slightly. The shells are rougher than those of clams. The green spot in the oyster is the digestive gland (often improperly called the liver), and not the digestive tube or its contents, as commonly supposed. Oysters and other salt-water mollusks are often left above water at low tide.

Distribution of Oysters. — Oysters are abundant along the Atlantic coast, south of Cape Cod, and in the Gulf of Mexico. In former times they occurred north of Cape Cod, but are now rare. Other species are found on the Pacific coasts and on the coasts of Europe, at the Cape of Good Hope, in Japan, and Australia. Chesapeake Bay is the center of the oyster industry, and the British market is now largely supplied from our beds, as we have not only the most abundant supply, but ours are the best in the world.

The Oyster Season. — The common saying that oysters are good only in months containing the letter "r," is partly wrong and partly right. Oysters are good to eat at any time of the year when freshly taken from the water. But during their breeding season — June to August — they do not bear handling so well, and are more likely to spoil. It is more profitable, too, to leave them undisturbed at this time, that they may increase enough to maintain their numbers.

The Shipworm. — As the name implies, this mollusk is wormlike. It sometimes becomes ten inches long and half an inch thick. It bears a small bivalve shell at its larger end. It burrows in wood, doing great damage to ship timbers, buoys, wharves, etc. The first stages of development are like those of many other bivalves. If the larva cannot find

wood, it soon dies. The hole by which the larva enters the wood is hardly larger than a pin head, but as the animal grows it excavates a constantly widening tube, thus imprisoning itself for life. Just how it burrows is not certainly known. It does not feed upon the wood, the fine sawdust being carried off through the excurrent siphon. Its food consists of microscopic plants and animals, which are brought in by

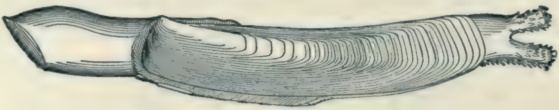


FIG. 76. RAZOR SHELL CLAM.

currents, as in the clam, and its only communication with the outer world is through the small hole by which it first entered the wood. Shipworms work rapidly, often completely honeycombing the wood. But no matter how many of them there are in the wood, their tubes never interfere with one another, but there is always left a thin partition between. They avoid iron rust, so timbers are protected by driving them thickly with broad-headed nails. The copper sheathing of hulls of ships is the best protection. Shipworms caused the famous dam break in Holland at the beginning of the last century.

The Razor Shell Clam. — The razor shell clam has a shell somewhat resembling in shape and size the handle of a razor. The foot projects at the anterior end, the siphons at the posterior end. These clams make vertical holes in the sand and can dig rapidly. At low tide the posterior end may be seen projecting from the sand, but unless the collector approaches quietly and seizes the clam quickly, it is almost sure to escape. They seem to be very sensitive to vibrations, and probably become aware of approach through these rather than through hearing or sight, although they are somewhat sensitive to light.

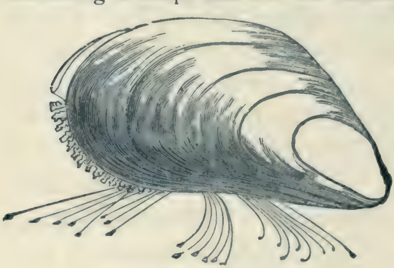


FIG. 77. MUSSEL.
With threads by which it is attached.

The Salt-water Mussel. — One of the most common marine bivalves is the mussel. The shell is usually dark or purplish, and rather thin

and weak. The mussel is found attached to rocks by means of a number of yellowish threads, the byssus, which grow from the base of the small foot. Mussels are found widely distributed along the coasts in most seas. They are used to a considerable extent as food in some countries.

The Giant Clam. — Probably the largest bivalve known is a marine clam of the genus Tridacna, found in Eastern seas. The soft body sometimes weighs twenty pounds, and the two valves of the shell together may weigh five hundred pounds.

The Scallop. — The outline of the shell as seen from one side is nearly circular. The two valves are not equal, one being less convex

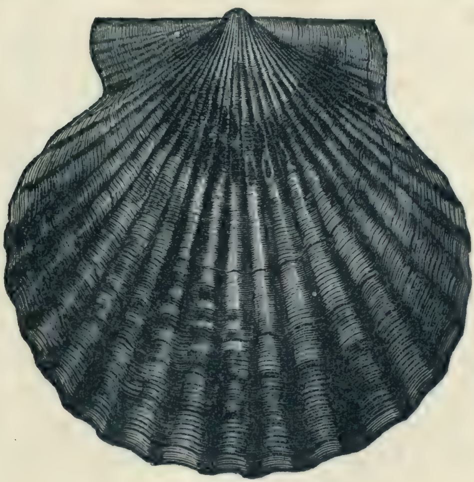


FIG. 78. SCALLOP.
The crusaders' badge.

than the other, sometimes perfectly flat. While at rest the scallop lies on the bottom with its valves widely gaped open. The scallop has a row of eyes along the margin of each mantle lobe. When an enemy approaches, the shell is quickly and powerfully shut by the one strong adductor muscle. This forcibly ejects the water, and by reaction the scallop is driven through the water, hinge foremost. The foot is rudimentary or lacking. The scallop is used for food; the adductor muscle,

however, is the only part eaten. It has a sweetish taste. The scallop shell was worn as a badge by the crusaders, as evidence of having visited the Holy Land.

Pearls. — These are formed of *nacre*, the material which constitutes the inner layer of the shell. They begin as deposits around grains of sand or other foreign objects that have gained entrance within the shell. They are usually found between the mantle and the shell, but may be in almost any of the soft parts. It is said that the Chinese introduce little images into the cavity of the pearl oyster, leaving them to become coated over with *nacre*. The most valuable pearls are usually obtained from the pearl oyster, but they are often found in certain species of fresh-water clams. The most celebrated pearl fisheries are in the Persian Gulf.

Characteristics of the Bivalve Mollusks. — The clam and most of the other bivalve mollusks have the following characteristics, and have received various names, according as any given writer places special emphasis on one characteristic or another: —

1. There is no head; hence some designate the group Acephala.

2. There are large, leaflike gills, from which comes the name Lamellibranchiata.

3. There is usually a muscular, tongue-shaped or hatchet-shaped foot, giving rise to the term Pelecypoda.

4. The mantle consists of two lobes, each lobe lining a valve; hence they are called Bivalve Mollusks.

CHAPTER VIII.

BRANCH MOLLUSCA.

CLASS GASTROPODA.

THE gastropods include the snails and slugs. They are of many kinds, terrestrial and aquatic, in fresh water and in salt water, shelled and shell-less, symmetrical and unsymmetrical, herbivorous and carnivorous.

The Shell. — The shells of gastropods are usually of one piece, therefore they are often called univalves in distinction from the bivalves. This one-pieced shell is almost always in the form of a cone. Sometimes the cone is nearly straight, as in the tooth-shells; again it is in the form of a very low, wide cone, as in the limpets; but in the great majority the cone is twisted into a spiral, making a thick, short cone out of a long and slender one. Sometimes this primary cone is wound upon itself to form a plane spiral like a watch spring, as in Planorbis. But ordinarily the spiral is an ascending spiral, which may be illustrated by holding the outer end of a watch spring and pushing the inner end out

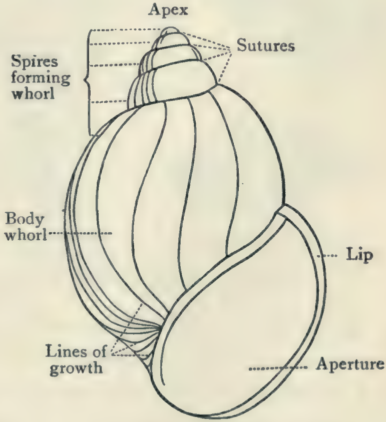


FIG. 79. PARTS OF A SNAIL SHELL.

at right angles to the plane of the flat spiral. By pushing out the center, first to the right and then to the left, we may illustrate both the right-handed and the left-handed shells. A very good substitute may be made by winding a narrow strip of paper around a lead pencil at one end. This, unwound, forms a flat spiral, representing the discoid shell. By pushing the center, first to one side and then the other, illustrate the right- and left-hand shells. Lay snail shells alongside a common wood screw; those having the whorls run the same way as the threads of the screw are right-

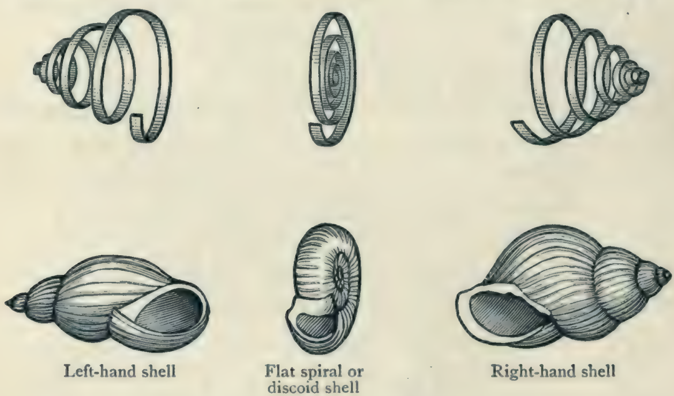


FIG. 80. COMPARISON OF KINDS OF SNAIL SHELLS.

hand shells; those with the whorls twisting in the opposite direction are left-hand shells.

The structure and composition of the shell are essentially the same as in clams, the lines of growth usually showing plainly parallel to the border of the lip.

The Operculum. — Nearly all sea snails, and many fresh-water snails, have a trap door attached to the hinder part of the foot, with which they close the aperture of the shell when the body is drawn in. This covering is the opercu-

lum, and grows by concentric rings to keep pace with the continually widening aperture.

The Lingual Ribbon. — In the floor of the mouth is a ribbon-shaped membrane bearing on its upper surface many rows of fine, sharp teeth. This ribbon passes over a pad of cartilage, being pulled forth and back by muscles. It acts like a rasp, wearing away the surfaces to which it is applied. As it is worn away in front, it is pushed forward by a new growth behind. In addition to the lingual ribbon, many

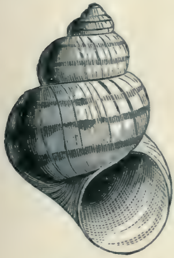


FIG. 81.

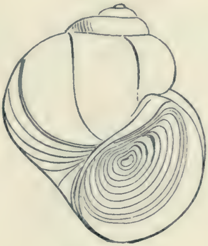


FIG. 82.

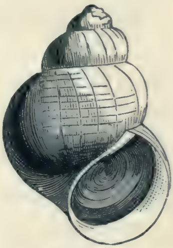


FIG. 83.

THREE SPECIES OF POND SNAILS.

In Figs. 82 and 83 the aperture is closed by an operculum.

mollusks of this group have also one or more jaw plates in the mouth, against which the ribbon works.

The Foot. — The foot in the gastropods is broad and flat. Resting upon this wide foot, the animal creeps or glides, leaving behind a slimy trail of mucus, which is abundantly secreted. The foot is symmetrical, and the anterior end is more or less distinctly marked off as the head.

The Digestive System. — The mouth opens on the front or under surface of the head. Watch a snail in an aquarium to see how the mouth works. From the mouth extends a short gullet, sometimes dilated into a crop, to the

stomach, which in turn is followed by the intestine. The intestine is usually twisted around so as to end in the mantle chamber near the edge of the aperture of the shell. Salivary glands are almost always present, and there is a large digestive gland around the stomach, as in the clams.

The Circulatory System. — This is on essentially the same plan as in clams. The blood comes from the gills, or lung, to the heart, and is thence pumped to the other parts of the body. There is usually but one auricle in place of two found in the clam.

The Excretory System. — The gastropods have kidneys essentially like those of clams, whose ducts open into the mantle cavity. Owing to the one-sided development, usually only one kidney is retained.

The Nervous System. — The nervous system is primarily about the same as that of the clam, consisting of several pairs of ganglions connected by nerve cords. The twisting of the body in many of the univalves involves the nervous system so that the nerve loop becomes twisted into the shape of a figure 8.

Sense Organs of Gastropods. — The eyes of the snail are described below. It is doubtful how well a snail can see, but it can discern light from darkness and can perceive quick movements.

A sense of touch belongs to the whole surface of the body, but is more acute in the tentacles. At the base of the gills are organs called "osphradia," or "smelling patches," being perhaps organs for testing the quality of the water. Land snails can detect odors, and the seat of the sense of smell seems to be in the tentacles.

Respiration in Gastropods. — The majority of the gastropods breathe by means of gills. Between the mantle and

the body, near the aperture of the shell, is a space called the mantle cavity. In this space lie the gills, but in many cases but one gill is developed.

Air-breathing Gastropods. — In land snails, slugs, and numerous fresh-water snails, the mantle chamber becomes more shut in, leaving a narrow opening, which is near the right side in right-hand snails, and on the left in the left-hand snails. Through this opening, which is kept closed most of the time, air is taken into the cavity, which acts as a lung. The blood circulates around the walls of the lung cavity, and is thus brought close to the air, so that an interchange can take place between the two.

The Land Snails. — These are abundant in damp woods, especially in limestone regions. Their shells are usually thin. Land snails have two pairs of tentacles, with eyes at the tips of the upper or longer pair. The eyes can be pulled in, the tip disappearing first, as when in pulling off a glove the tip of the glove finger sticks to the end of the finger. If the tip of one of these tentacles is cut off, it will be reproduced, and it is said that this has been done twenty times in succession.

Land snails usually have no operculums; but at the approach of winter, or of a period of drouth, they bury themselves in the ground, and pull the body in until the foot is even with the edge of the aperture. A layer of mucus is secreted which completely closes the aperture. In some cases limy material is added, and, in any case, the covering soon hardens. Sometimes the snail then withdraws still farther, and makes another such barrier, or even several. In the spring, or at the return of moisture, the temporary door is cast off, and the snail resumes its activity. Snails have great vitality, and have been known to survive in this shut-in condition for six years without food.

Most kinds of snails lay their eggs in strings, masses, or clusters; but the land snails deposit theirs singly, burying them or depositing them in moist places.

The French follow the usage of the Romans in eating the land snails, and they are now imported into the United States from Europe by Eastern dealers.

In Europe snails do considerable damage in gardens, but they do not seriously affect us.

Slugs. — Slugs are air-breathing, terrestrial gastropods, almost always destitute of a shell. They are to be found in moist woods, especially under the bark or in the decaying trunks of fallen trees.

On the anterior dorsal surface is a fleshy plate, the mantle, and near the right edge of this is the breathing pore, lead-

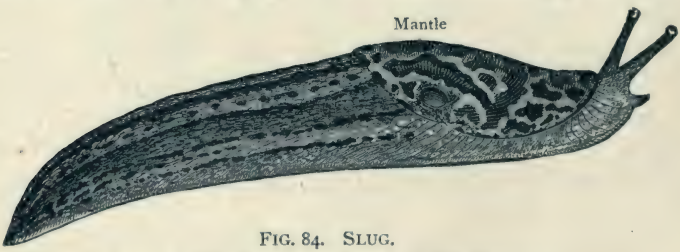


FIG. 84. SLUG.
Near the lower border of the mantle is the respiratory pore.

ing to the lung. As in the land snail, there are two pairs of tentacles, with eyes at the ends of the upper (longer) pair. The body is elongated; but when the animal is disturbed, it draws up into a short, compact lump.

Slugs are nocturnal, hence are less conspicuous than snails. They do considerable damage in gardens, rasping off the surfaces of the leaves. Their presence is also indicated by the slimy trails which they leave behind. One of the most effective ways of checking them is to sprinkle coal ashes over and around the plants they are attacking.

The Pond Snails. — The pond snails have the mantle cavity transformed into a lung, as in the land snails. They frequently come to the surface of the water to get air, and may be seen first to emit a bubble of the contained air, take a new supply, and again descend to resume their

Fig. 85.

Fig. 86.

Pond Snails Creeping.

The largest part extending from the shell is the foot. There are three other protruding organs: (1) the proboscis, in the center; (2) the two tentacles, with an eye at the base of each; (3) outside the tentacles, the respiratory tubes, one of which takes in water, the other sending it out. In Fig. 85, the dark semicircle back of the shell is the operculum.

eating. They are exclusively herbivorous, and in an aquarium may be observed cleaning off the layer of green scum, mostly consisting of algæ, which grows on the sides of the aquarium.

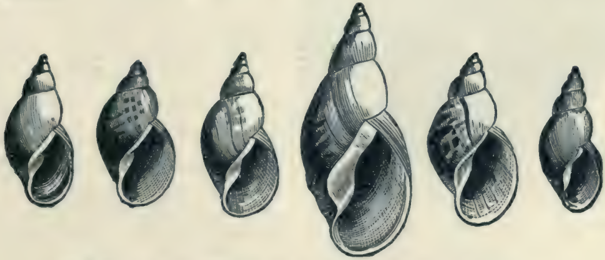


Fig. 87. Variations in a Common Pond Snail.
After Morse, from Packard's *Zoölogy*.

There is but one pair of tentacles, at the bases of which are the eyes. Only a few pond snails have operculums.

The eggs are laid in clusters, usually enveloped in a gelatinous mass; and in an aquarium are usually deposited on the side of the glass in a very favorable place for watching their development. There are three common genera, — Limnea, a right-hand shell; Planorbis, a discoid shell, or flat spiral; and Physa, a left-hand spiral (Fig. 80).

The River Snails. — These are not entirely distinct from the pond snails; still, they nearly all breathe by means of gills, and most of them have operculums. Being gill breathers, they of course do not come to the surface to breathe, hence are not usually so conspicuous. Some of them have a projecting tube on each side of the neck, the water entering through one of the tubes to the gill, and passing out through the other. The eyes are like those of the pond snails in being borne at the bases of the one pair of tentacles. In some of the river snails the young are brought forth alive.

FIG. 88. A LARGE SEA SNAIL (NATICA).
It feeds on clams, etc., boring through their shells.

Sea Snails. — These are found chiefly along the shore, not often in very deep water. They are numerous in kinds and individuals, and vary greatly in both color and form. In size they vary from almost microscopic to a foot and a half or more in length. They also vary greatly in shape, from globular (Fig. 88) to slender tapering forms resembling screws. The shell is usually right-handed, and the majority have operculums. Nearly all breathe by means of gills.

A Drilling Sea Snail. — Natica (see Fig. 88) is common on the New England coast. It is one of the largest of the snails found along the northern shores, sometimes reaching a length of five inches. Natica is carnivorous, and lives mostly on clams and other bivalves. It burrows in the mud or sand; and when it finds a clam, it uses the lingual ribbon and bores a hole through the shell, rotating its own body meanwhile.

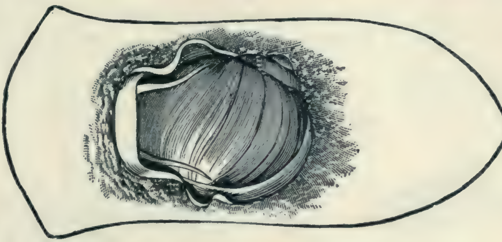


FIG. 89. A SEA SNAIL (NATICA) CRAWLING.
Showing the very large foot (surrounding the shell).

It produces as neat a countersunk hole as any made by a drill for the head of a screw such as may be seen in any door hinge. After the hole is made through the shell, the soft body of the clam is eaten.

Sea Slugs. — Sea slugs are found near shore, on rocks or among seaweeds. Many of them are devoid of shells when adult, but all have shells in their earlier stages. Many of them are symmetrical externally, but few are so in their internal structure, — the intestine, for example, usually ending on the right side. In some the gills are covered, in others exposed. The gills often project as leaflike appendages on the posterior part of the dorsal surface; and the whole animal, in form and color, has such a close resemblance to the seaweeds, on which it crawls and feeds, that it escapes the enemies to which, in its defenseless condition, it would be an easy prey. Some of the sea slugs can swim, and usually do so inverted, with the flat surface of the foot at the surface of the water. When the adult has a shell, it sometimes has its edges covered by the overlapping mantle, and sometimes is completely inclosed by a sac like mantle.

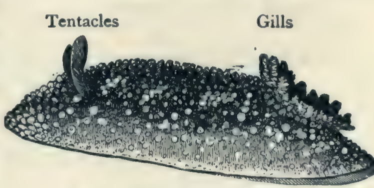


FIG. 90. NAKED MOLLUSK.
From Kingsley's *Comparative Zoölogy*.

Limpets.—Along the shore there are to be found gastropods with low conical shells, clinging close to the surface of the rocks. They may be scraped off by a quick motion with a dull knife, but if they are first alarmed they draw down and adhere so firmly to the rock that one is likely to break the shell in the attempt to dislodge them. The keyhole limpet is so named from the shape of the hole at the apex.

The Ear-shell or Abalone.—Closely related to the limpets is the "ear-shell" found on the California coast. There is

FIG. 91. LIMPET.
Surface view and side view.

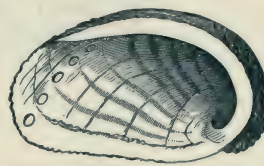


FIG. 92. ABALONE OR EAR-SHELL.
Furnishes mother-of-pearl for inlaid work.

FIG. 93. RED CHITON (kī'tŏn).

a row of perforations near one margin of the shell, through which tentacles project. The interior of the shell is pearly and of beautifully variegated color. It is known as "abalone," and is much used for inlaid work.

A Multivalved Mollusk.—Chiton is a very peculiar marine mollusk. It is low and flat, creeping like the limpets. But the shell consists of a series of eight pieces overlapping one another from the anterior to the posterior end. The animal is completely symmetrical, both internally and externally (Fig. 93).

CHARACTERISTICS OF THE GASTROPODA.

1. The gastropods have a foot which is developed as a broad, flat, creeping disk.

2. There is usually a well-developed head, with eyes and tentacles.

3. The majority have a univalve shell, but this is sometimes lacking.

4. Body often unsymmetrical.

5. There is a lingual ribbon.

CHAPTER IX.

BRANCH MOLLUSCA.

CLASS CEPHALOPODA.

THE cephalopods include such forms as the squid, cuttlefish, and chambered nautilus.

The Squid. — The squid is the best example of the group. It is abundant along the Atlantic coast. Squids swim in schools, and are frequently found following schools of young herring and mackerel, on which they feed. They

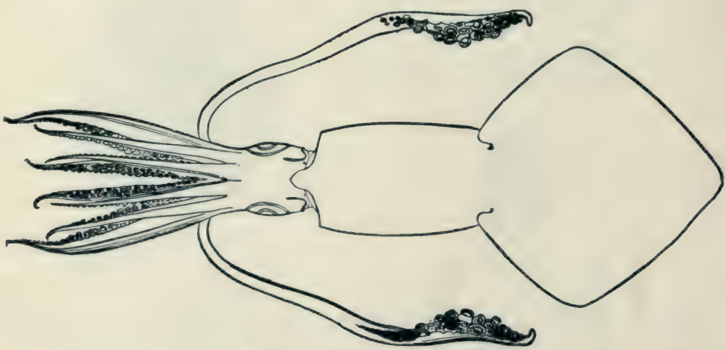


FIG. 94. COMMON SQUID.
From Packard's *Zoölogy*.

are chiefly nocturnal, though not infrequently seen in the daytime. After a storm the writer has seen the beaches on Cape Ann covered with them in the morning, where they have been left stranded by the receding tide.

The Form of the Squid. — Seen from above the body appears cylindrical. At the anterior end is a well-developed

head and a distinct neck. At the tail end are two triangular fins which together present the appearance of a diamond-shaped arrow point. Seen from below the body is conical or fusiform, ending in a distinct point behind, the tail fin covering about one third of the body. The fins are attached at the sides of the dorsal part of the hinder part of the body, and can be wrapped more or less around the tapering posterior end. The common kinds of squids seldom attain a length of a foot.

The Head. — From the front of the head project five pairs of arms, arranged in a circle around the mouth. Four pairs of these arms are short, and taper to a point. One pair are much longer, being nearly as long as the body, and are enlarged near the ends. On the inner surfaces of the short arms, and on one side of the club-shaped end of the long arms, are rows of suckers. These are button-shaped or saucer-shaped bodies, attached to the arms by stalks. The outer surface is hollow, and when applied to any surface the center can be retracted by the muscular stem by which it is attached, thus making a strong hold-fast. The long arms are sometimes called the "grasping arms."

On the sides of the head are the two large eyes, the most highly developed eyes among the invertebrates.

The Mantle. — There is an opening all around the neck where it projects from the mantle cavity. The whole external envelope of the body is the mantle, inside which is the conical body, with a space extending nearly all around it except along the dorsal line, where the outside of the body mass is attached to the inside of the mantle. The mantle is muscular and very powerful.

The Pen. — The squid has no external shell, and the only representative of one is a horny structure, somewhat

similar in shape to a feather. This is imbedded in the dorsal part of the mantle, extending nearly the whole length of the back. It is wholly inclosed in a capsule in the thickness of the mantle wall.

The Siphon or Funnel. — Projecting from the mantle cavity under the head is a funnel whose narrow end opens forward and whose wide end points back into the mantle cavity.

How the Squid Swims. — Water is taken into the mantle cavity through the open space around the neck. Then the edge of the mantle is contracted and is fastened to the neck and sides of the base of the funnel by a set of cartilages that have a sort of "hook and eye" arrangement. Then by the contraction of the mantle the water is forced out through the siphon, and by reaction the squid is rapidly driven backward through the water. So swift is its movement that it has received the popular name of "arrow fish." Squids sometimes dart clear out of the water, and, when kept in aquariums, thus jump over the sides. Their motion is amazing, not only on account of its swiftness, but because there is no manifest cause of the motion. They propel themselves by the outgush of water, which is invisible, and the change in size from the contraction of the mantle is so slight as to be unnoticed. To the uninstructed it is as inexplicable as the motion of a trolley car is to a savage. When the squid wishes to move slightly, it does so by gently flapping the tail fins.

The Ink Bag. — The squid has an ink bag, which lies near the rectum, and which opens near the anal opening, near the inner end of the funnel. When in flight from a pursuing fish, a discharge of ink is sent out in the strong gush of water through the siphon. This makes a dark cloud in the water, under cover of which the chances of

escape are greatly increased. This ink is the original "sepia" used as ink by the Chinese and Japanese. Some of this ink, from the fossil squid, has been used to make a drawing of the animal from which the ink was taken.

The Color of the Squid. — Ordinarily the dead squid is of a pale color, tinted with purplish. In the living animal the color is very changeable, passing quickly from red to blue or purple, and one part may have one of these colors while other parts have another color. This change of color is due to several different sets of colored cells, called "chromatophores"; these expand and relax under the control of muscles, which are in turn governed by nerves. The color changes in quick flashes, exceeding the quickness of blushing and pallor observed in the human face. This change of color is undoubtedly for the sake of protection, though one is inclined to wonder why such intense hues should be employed. As a school of squids are swimming along they are often seen to change their color abruptly, according to the bottom over which they are passing.

Methods of Escape from Enemies. — (1) The squid may elude observation by taking on the color of its surroundings. (2) By speedy flight. (3) In flight its chances of escape are increased by the discharge of ink, which makes the water turbid.

The Digestive System. — The brown beak projects from the center of the circle of arms in front of the head. It consists of a pair of hard, horny jaws, somewhat resembling the beak of a parrot, except that the upper jaw is much smaller than the lower, into which it shuts. In addition to the beak there is a lingual ribbon, as in the snails. From the mouth extends a long, narrow gullet. Well back in the body is the muscular stomach, which has a large cecum. The intestine then extends forward,

ending in the mantle cavity near the large inner end of the funnel. The excrement, as in the clam, is swept out by the water current. There are salivary glands; and a large digestive gland, often called the "liver," pours its secretion into the cecum.

How the Squid captures its Prey. — The squid is a voracious animal and lives largely on small fishes. It sometimes stealthily approaches a fish by almost imperceptible motions of its fins, until it is within grasping distance, when it suddenly seizes the fish and quickly kills it by biting it in the back of the neck. Again it swims swiftly, and suddenly darts among a school of fishes, and turns and kills its prey by a quick snap of its powerful jaws. It also eats crabs and other animals. While it is pursuing the smaller fishes, it may, in turn, be chased by larger fishes.

Respiration and Circulation in the Squid. — The squid has two plumelike gills attached to the under surface of the body, extending along the mantle cavity. The circulatory system is more highly developed than in any of the other mollusks.

The Nervous System. — The nervous system, too, is highly developed and concentrated, consisting of several pairs of ganglions in the head, forming a central brain, from which nerves extend to the other parts of the body. There is a protecting case of cartilage, a rudimentary cranium, supporting and partly surrounding the brain.

The Senses of the Squid. — The eyes are highly developed, and evidently have keen sense of sight. A number of squids may be lying side by side in the water, perfectly motionless, perhaps relying on their quietness and protective color. A sudden motion on the part of a person ob-

serving them may cause them to dart off like so many arrows. There is a rudimentary ear. Some authors say that the squid has the five senses which are best known in our bodies.

The Squid used as Bait. — Squids are used very extensively as bait in the cod fishery, a single small vessel sometimes using eighty thousand in six weeks. They are caught mainly by means of nets. They are either kept fresh for this use, or may be "pickled" in brine. They are also used in fishing for bluefish.

FIG. 95. OCTOPUS, FROM BRAZIL.
From Packard's *Zoölogy*.

Giant Squids. — Some species of squids have a body over nine feet long, with arms thirty feet in length. Some of these may have given rise to the stories of "sea serpents."

The Octopus. — As the name indicates, these forms have eight arms instead of ten, as in the squids and cuttles. The body is short and nearly spherical. Though the octopus can swim, it is very much less active than the preceding forms, spending most of the time crawling over the bottom, resting on the basis of the circle of arms with the body held above. The arms are more or less connected by webs at the base. There is neither internal nor external shell. A Pacific coast octopus has body a foot long, the arms having a radial spread of twenty-eight feet.

Many weird tales are told of the octopus, most of which have little or no foundation. In fact, there is no satisfactory evidence that an octopus ever intentionally attacked a human being. In countries adjacent to the Mediterranean the octopus is largely used as food.

The Nautilus. — The nautilus is closely related to the squids and cuttlefishes, but has the body inclosed in a flat-spiral shell. From time to time the animal moves forward and partitions off the space in the shell which it formerly occupied, the live animal occupying only the

FIG. 96. CHAMBERED NAUTILUS.
Showing chambers with soft body in outer chamber.
From Packard's *Zoölogy*.

outermost space in the shell. It retains its hold on the smallest and oldest portion of the shell, however, by means of a slender fleshy cord which passes through a series of holes left in the partitions. The inner, abandoned spaces are filled with gas. From this fact of growth the animal is commonly called the chambered nautilus, though it is also called the pearly nautilus, from the pearly lining. It lives in the South Seas.

Fossil Chambered Shells. — While the nautilus is almost the only living form of this peculiar plan of growth, there are many fossil chambered shells. Two of the most noteworthy of these are the Ammon-

ites, a spiral form very similar to the nautilus, and a perfectly straight conical shell, hence named Orthoceras.

The Cuttlefish. — In the cuttlefish the lateral fins extend along the whole of the length of the side, and the body is less sharply conical. Though essentially like the squid, they are less swift in their flight. In the sharp prow of the squid one sees the build of a racing shell, while the greater width of the cuttlefish suggests the increased breadth of beam in an ordinary rowboat. Cuttlefishes feed on crabs, clams, and fishes. The internal shell of the cuttlefish is calcareous, instead of horny as in the squid, and is well known from its use in furnishing limy material to canary birds. The ink of the cuttlefish is the basis of the pigment sepia. Cuttlefishes live near shore and are used extensively as food (in the Old World) as well as for the ink and cuttle bone.

CHARACTERISTICS OF THE CEPHALOPODA.

1. There is a distinct head with highly developed eyes.
2. The foot has developed around the head (hence the name Cephalopoda), and is divided into a number of arms.
3. Part of the foot develops into a funnel-like siphon.
4. The shell may be external, internal, or lacking.
5. Chromatophores are found in the skin.
6. There is a beak and a lingual ribbon.

CHARACTERISTICS OF THE MOLLUSKS.

There is such a great diversity among the mollusks that it is very difficult to make any concise statement of their common characteristics. Some have shells, others none; some are aquatic, others terrestrial; some live in fresh water, others in the sea; some breathe by gills, others by lungs; some are herbivorous, some carnivorous; some are free, others sessile; the limpet, though free, practically is glued to its place on a rock; the slug is so slow that we have borrowed his name to make a common adjective,

while the scallop swims actively; clams and oysters feed on microscopic forms swept in by currents of water, while the cephalopods prey upon the most active fishes; there is strong contrast between the monotonous existence of the headless clam, burrowing in the mud, and the free life of the cuttlefish, with its distinct head and highly developed eyes; the oyster is fixed to his spot, almost as passive as a sponge, while the squid darts so swiftly that it is called the arrow fish.

Nevertheless the following characteristics belong in common to the various classes of mollusks: —

1. Aside from the shell the body is soft; hence the name "mollusk," *soft*.

2. The body is unsegmented, in distinction from the arthropods, the vertebrates, and many worms.

3. There is an extension of the skin called the "mantle," which usually produces a shell, univalve, bivalve, or rarely multivalve.

4. There is usually a ventral muscular extension, the foot, which, in most forms, serves in locomotion.

5. They are mostly bilaterally symmetrical, but some are much distorted.

6. The nervous system consists of about three pairs of ganglions, connected by nerve cords.

CLASSIFICATION OF THE MOLLUSCA.

As all earlier classifications are based on superficial characteristics, it was to be expected that the first classifications of mollusks would be by their shells. Hence the science of Conchology. But now we class the mollusks, as other groups, by their general plan of structure, mainly of the soft parts, for these parts make the shell, and the shell does not mould them.

They have been classed according to the head into Acephala (headless, clams), Cephalophora (head-bearing, snails), and Cephalopoda (head-footed, squids).

The classification here adopted is based on the foot and presents three chief classes: —

1. Pelecypoda (hatchet-footed); example, the clam.
2. Gastropoda (stomach-footed); example, the snail.
3. Cephalopoda (head-footed); example, the squid.

CHAPTER X.

BRANCH CHORDATA.

THIS branch is mainly composed of the vertebrates, or backboned animals, that is, fishes, amphibians, reptiles, birds, and mammals. But it is now found necessary to class with them certain other animals formerly regarded as invertebrates. Hence the old branch Vertebrata is made a subbranch, and, with two other subbranches, included in the branch Chordata. The chordate animals are characterized by the possession of a dorsal chord or notochord. This is a supporting rod extending along the dorsal region between the body cavity and the main nervous system or spinal cord. While the notochord is always present in the young, it is, with a few exceptions, replaced in the adult by a segmented cartilaginous or bony axis, which is known as the spinal or vertebral column. In other words, the notochord is a sort of forerunner of the backbone.

Subdivisions of Chordata. — The branch Chordata is divided into three subbranches: —

1. Adelochorda, wormlike, marine forms (Balanoglossus).
2. Urochorda, the tunicates or ascidians.
3. Vertebrata, lancelet to mammals.

Division A. — Acrania, the lancelets.

Division B. — Craniata.
- (*a*) Cyclostomata, without jaws (lampreys).
- (*b*) Gnathostomata, with jaws (true fishes to mammals).

SUBBRANCH UROCHORDA.

As an example of the urochordates we may take the common ascidian. Such forms are sometimes called "sea peaches" or "sea pears," indicating the size, shape, and general appearance. They are attached by one end to rocks or shells or even to a muddy bottom. There are two holes, one at, and the other near, the free end. When the living animal is disturbed, it ejects water from both of these holes, hence the more common name, "sea squirt." The tough muscular external coat, or tunic, also gives the name tunicata. They are all marine.

Structure of an Ascidian. — Inside the outer wall, or tunic, is a lining, the pharynx, which hangs free below its attachment near the larger opening, the mouth. The pharynx is perforated by many small apertures through which water is driven by cilia. From the space around the pharynx, the peribranchial chamber, the water passes out through the second, or exhalant, aperture. From the lower end of the pharynx arises the gullet, which soon enlarges into the stomach. A relatively short intestine empties into the peribranchial chamber, where the outgoing water current catches the refuse of digestion. There is a simple tubular heart, which is unique in its action. After pumping the blood in one direction for a few beats, it reverses its action and sends the blood the other way. The nervous system is very simple, consisting mainly of a ganglion between the two apertures (see Fig. 97).

Development of Ascidians. — In the above account of the structure of an ascidian there is no trace of relationship to the other chordates, and so long as the structure of the adult only was known, no one even guessed at its real affinities. But the study of its development threw light on

the subject. It was found that the larval ascidian possesses a long tail in which is a distinct notochord and an elongated nerve cord. But early in life the larva attaches itself by its head, the tail gradually disappears, and the elongated nerve cord becomes shortened to a mere ganglion. In the

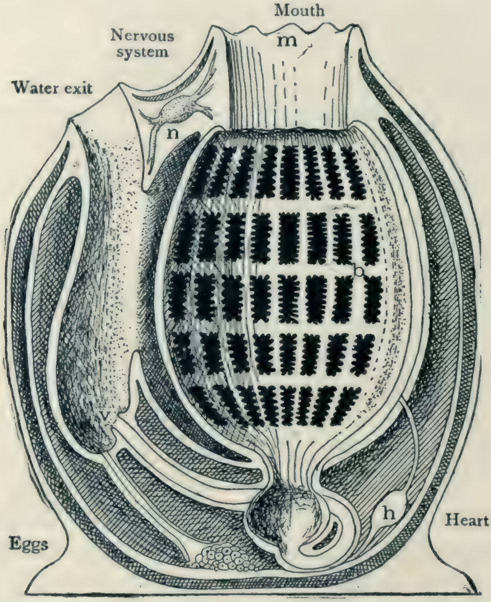


FIG. 97. DIAGRAM OF A TUNICATE OR ASCIDIAN (SEA SQUIRT).
From Kingsley's *Zoölogy*.

sessile adult animal no trace remains of the primitive notochord. This illustrates what is called "retrograde development"; or, in simple words, the ascidian is a degenerate chordate, perhaps even a degenerate vertebrate. This is one instance of degeneration in which the real relationship is indicated by the structure of the young rather than by that of the adult.

Other Tunicates. — Some tunicates are minute and free-swimming by means of a vibratile tail. Other small forms are barrel-shaped, and exhibit a marked "alternation of generations." Many of the tunicates live and multiply by budding in colonies.

SUBBRANCH VERTEBRATA.

The Lowest Vertebrate. — To the beginner it would seem easy to determine whether or not an animal has a backbone, and so to decide whether it is a vertebrate or an invertebrate. But let us take a glance at what is by many authors regarded as the simplest of the vertebrates.

The Lancelet. — The lancelet (Branchiostoma, or Amphioxus) is fishlike in form and general appearance, only two

FIG. 98. DIAGRAM OF LANCELET.

Above (dotted) is the nervous system; below it (cross-lined) the notochord; the mouth is surrounded by a circle of tentacles; below the notochord is a row of gill slits; the vent is near the posterior (right) end below. From Kingsley's *Zoölogy*.

or three inches long, and nearly transparent. It is marine, being found in warm waters. Specimens are taken along the south Atlantic coast. The lancelet has a notochord extending to the anterior end, or the snout. There is a nerve cord along the dorsal side of the notochord, but the anterior end is hardly well enough developed to deserve being called a brain. It has blood tubes, but no heart. There is a tail fin, but no limbs, not even paired fins. The mouth is surrounded by a circle of fringelike tentacles. Back of the mouth extends the capacious pharynx, whose walls are perforated by numerous ciliated gill slits. At the

posterior end of the pharynx the intestine continues to the anus, situated posteriorly and ventrally. By the action of the cilia water is taken into the mouth, passes through the slits in the wall of the pharynx, and enters a space around the pharynx, called the atrial or peribranchial chamber, whence it escapes to the exterior through a ventral opening called the atrial pore. The lancelet usually lies buried in the sand, with only the mouth projecting. It gets both food and oxygen from the water, which is circulated through the body by means of ciliary action. The lancelet occasionally swims by fishlike movements.

Classification of the Lancelet. — It might, at first thought, seem strange that so simple an animal should be classed with a group having such complex structure as the vertebrates. The lancelet has, in fact, been placed with the mollusks, and later with the fishes, but is now located at the foot of the vertebrate series, chiefly on account of the possession of the notochord and the dorsal nervous system. It is really hard to locate an animal with colorless blood, and with neither skull, brain, heart, auditory organs, paired eyes, nor paired fins.

The student who gets his ideas of classification almost entirely from reading is apt to think that the animal kingdom is divided into groups separated by clear and distinct dividing lines. But when he undertakes the actual examination of any considerable series of animals, he often finds that two groups, which he regarded as distinct, actually merge one into the other so gradually that he finds it difficult to see just where the line of division should be drawn. The line of demarcation must frequently be so drawn that it cuts across some intermediate forms, part of whose characteristics lie on one side and part on the other. In some cases the intermediate forms are living; in other cases the

"connecting links" are represented only by fossil forms, as, for example, the extinct animals that connect the reptiles and the birds.

The lancelets are plainly on the threshold of the vertebrate household. By some authorities they are denied admittance, and must wait just outside. Others allow them barely to cross the threshold and humbly take their place by the door, the lowest of the great branch at whose head stands man.

Distinction of the Lancelet from Other Vertebrates. — On account of the poorly developed brain and the absence of a cranium, the lancelet is placed by itself in a division called Acrania, while all the other vertebrates are designated as Craniata, from the presence of a skull and the higher development of the brain.

CLASS CYCLOSTOMATA.

The lowest of the craniate vertebrates are the Cyclostomata. This class includes the lampreys, or lamprey eels, as they are often called, and the hagfishes. They are eel-like in form, without scales, and with smooth, slimy skins. They have no jaws, but a round, sucking mouth, hence they are sometimes called the "round-mouthed eels." There is a single nostril on top of the head. They have dorsal and caudal fins, but no paired fins. There are several pairs of purse-shaped gills, hence they are called by some authors Marsipobranchii. The skeleton has no trace of bone, being wholly cartilaginous and very imperfectly developed. The internal organs are, in many features, similar to those of the true fishes.

Lampreys are rather widely distributed. They are found along the Atlantic coast and ascend the rivers

Some appear to live permanently in our large lakes. By their sucking mouths they attach themselves to fishes,

FIG. 99. LAMPREY EEL.
After Goode. — From Kingsley's *Zoölogy*.

sucking their blood, or even penetrating their bodies. They are the only vertebrates known to live a parasitic life. In Europe the sea lampreys are valued as food.

CLASS PISCES.

Example. — The Ringed Perch.

Life of a Perch. — If one stops to consider what are the chief objects in life with a fish, he soon sees that it is well expressed in the words "to eat and not be eaten."

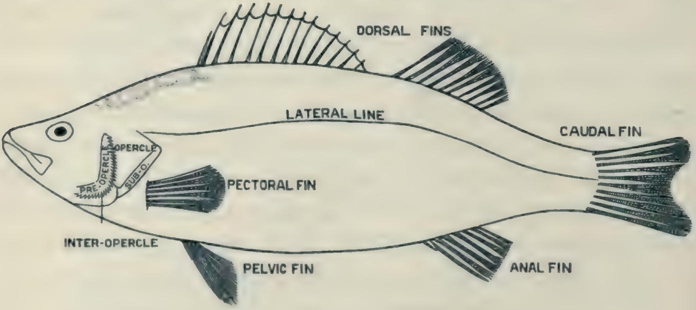


FIG. 100. EXTERNAL FEATURES OF A PERCH.

In order to secure food and escape enemies the fish must have sense organs and organs of locomotion.

How the Fish Floats. — Before taking up the question of locomotion in fishes, let us first consider how it is that the fish can keep its place in the water without effort, neither rising nor sinking. A freshly killed fish usually sinks, showing that its body is slightly heavier than water. Almost every one knows that after a fish has been dead a short time it usually floats (commonly with the ventral surface upward). This is due to the development of gases in the intestines.

Most fishes have air bladders (or swim bladders), by means of which they can regulate their position in water. By shortening the muscle fibers in the walls of the air bladder, or in the walls of the abdomen, the air bladder is made smaller and the fish sinks. By relaxing the muscles the air expands, the fish as a whole is relatively lighter, and consequently rises.

Most fishes have swim bladders, and stay in midwater, that is, do not rest most of the time on the bottom. On the other hand, many fishes that rest most of the time on the bottom are without a swim bladder. In some fishes, as the perch, the air bladder is attached to the walls of the abdomen. In others, for example, suckers, the air bladder is free from the walls of the abdomen and is readily removed, and in dressing the fish the air bladder is taken out with the other internal organs.

Locomotion of Fishes. — Most fishes have the body compressed; that is, flattened from side to side. The thickest part of the body is in front of the middle. The longer taper is toward the tail, and this gives greater flexibility and freedom of motion to this part. When the fish wishes to swim, it makes a sideways and backward stroke of the tail. This sends the body ahead and sideways; that is, if the tail is struck back and to the right it pushes the fish

forward and to the left. But the fish quickly makes another stroke in the opposite direction, and as a result of the two he may go straight ahead. The fish may simply make the double stroke, right and left, and without further strokes dart straight forward, but usually there is a succession of strokes by which it is enabled to pursue a straight course. It should be noted that nearly all fishes that can swim rapidly have a pointed snout to diminish the resistance. Resistance to the motion of the fish is still further reduced by the mode of overlapping the scales and the coating of mucus. The fins, too, point backward.

How the Perch Eats. — The perch feeds on minnows, worms, water insects, and larvæ of various sorts, which it catches and swallows alive. The extensibility of the mouth is very great. The upper jaw can be protruded so that the opening of the mouth is a wide circle, nearly as large as the greatest circumference of the fish at any point. It has been noticed that when the fish keeps the mouth closed the snout presents a sharp point; this is in marked contrast with the large opening shown when the fish is about to ingulf its prey. It must be kept in mind that the fish has no special organs of prehension, but must do all the work of catching with the mouth alone. There are numerous teeth, but they are not large, serving merely to hold the struggling captive, and used little, if any, for either tearing or masticating it.

Digestive Organs of the Perch. — The mouth narrows back into the wide gullet, which is kept closed except when swallowing. The gullet leads into a fair-sized stomach, which ends blindly behind. The intestine arises from one side of the anterior end of the stomach. At the beginning of the intestine are three short blind tubes, the ceca. The intestine takes one or two turns and terminates in

the anal opening. As the perch is carnivorous, we should naturally expect a relatively short intestine. In the anterior part of the body cavity lies the liver. On its posterior surface is the bile sac, which may be greenish or yellowish, or, if empty, have little color. It is then hard to discover, and appears like a small worm-shaped appendage to the liver. A duct conveys the bile into the intestine.

Circulatory System of the Perch. — The heart of the perch is almost literally "in his throat." The heart is in a separate cavity, the pericardial chamber, with a firm partition between it and the main body cavity. The heart consists of three parts, through which the blood passes in order from behind. The venous sinus receives the blood from all parts of the body; from

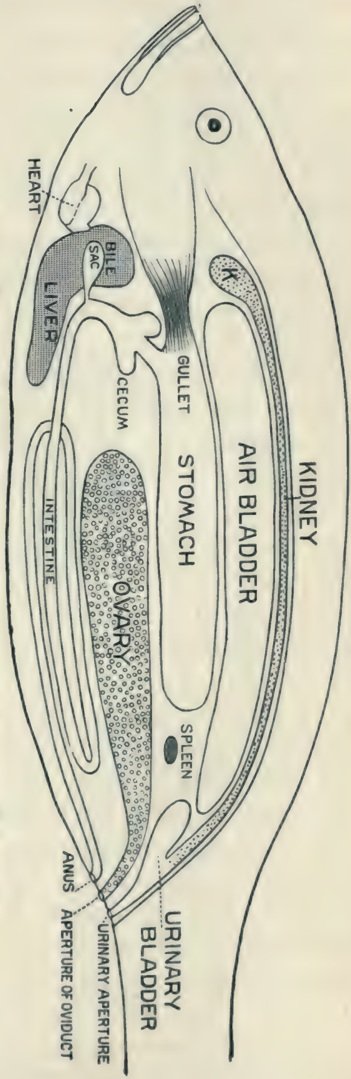


FIG. 101. DIGESTIVE, EXCRETORY, AND REPRODUCTIVE SYSTEMS OF A PERCH.

the sinus the blood enters the auricle, which also is thin-walled; from the auricle it passes into the ventricle, whose walls are thick and muscular, and by whose contraction the blood is pumped clear around the whole circuit to the heart again. From the anterior end of the ventricle runs forward the artery leading to the gills. The first part of the artery is often enlarged and is sometimes called the arterial cone or arterial bulb. This artery divides into four branches on each side, one to each gill. After traversing the gills, the blood-tubes (still called arteries) unite on each side, and later the two arteries thus formed unite to form one dorsal artery which supplies all parts of the body. The small arteries subdivide and form capillaries, which pervade all the tissues. The capillaries unite to form the veins, which again bring blood to the heart.

How the Perch Breathes. — When watching a live fish one sees that the mouth and gill openings open and close alternately. It can easily be proved that water enters the mouth and passes out through the gill openings; thus a pretty constant current of water flows over the gills. Each gill consists of a bony arch, hinged at the upper and lower ends and jointed in the middle. Along the posterior border of each gill is a red fringe, the red color being due to the red blood within, which shows through the thin, delicate coverings of the gill filaments, as the individual parts of the fringe are called. As the blood comes up into the gill from the artery below, it goes off into small side branches running out into the filaments; when it returns along the other margin of the gill filament, it enters another artery to pass out at the upper end of the gill. Thus it is clear that there is a constant flow of blood in very narrow, thin-walled tubes in the thin-covered gill filaments; there is also a stream of fresh water flowing

over the outside of the filament. The blood entering the gills has lost oxygen in passing through the muscles and other working tissues of the body; so, in passing through the gills, it absorbs oxygen from the water through the comparatively thin wall that separates it from the water. On the other hand, the blood entering the gills is loaded with carbon dioxid and other waste matter that it has picked up in the muscles and other tissues; this passes out into the water and is carried away. It should be noted that the current of water is in the right direction to keep the delicate gill fringe evenly extended, instead of matting and tangling it together, as it would be likely to do if the water current were reversed.

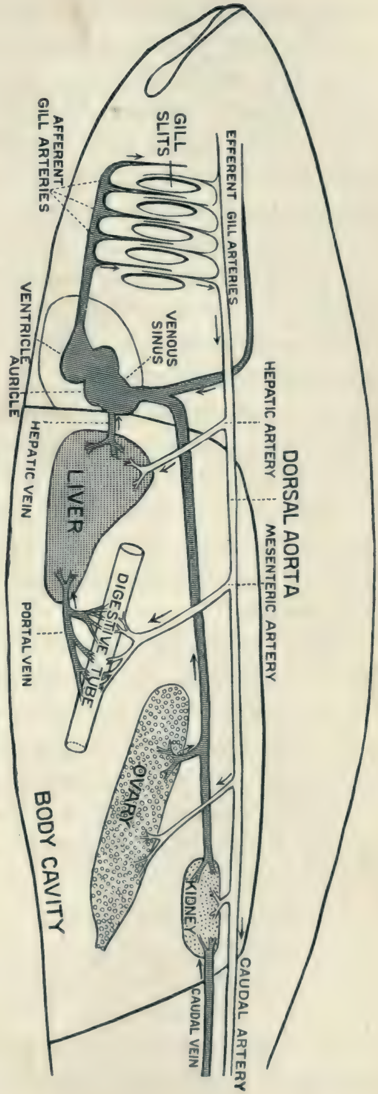


FIG. 102. CIRCULATORY SYSTEM OF A PERCH.

The Protection of the Gills. — The gills are really external organs. From the nature of their work they must have very thin external coatings, and so are correspondingly delicate. Hence the strong yet flexible gill cover. The more technical name for this is the opercle. It consists of several parts, the opercle proper, subopercle, preopercle, and interopercle (see Fig. 100). Overlapping from front to back, and being under muscular control so that they can be held down with considerable force when necessary, they constitute a very good shield. In addition to the opercle there is a gill cover below, called the branchiostegal membrane. It is a tough, yet thin, membrane supported by several small curved bones, the branchiostegal rays. A fish carries about its head organs that are of vital importance and of most delicate texture, yet it dashes among more or less rough aquatic plants and after fishes that are well armed with spines. It is safe in doing this because of the double set of gill covers, one soft and one bony.

When the perch swallows a spiny fish, still struggling, will not the soft gills be torn from the inside, producing serious injury? The use of the bony, toothlike gill rakers projecting on the inner surface of the gill arches is now apparent. The gill rakers also serve as a strainer in swallowing smaller particles of food, and some authorities say that the gill rakers serve, to a certain extent, as teeth in crushing the food.

When the fish seizes its prey, it of course takes water into the mouth with it; but this is allowed to pass out through the gill openings, and probably only a little is swallowed with the food.

The Sense Organs of the Perch. — The perch has well-developed eyes, but without movable lids. If any one

doubts their keenness of sight, let him fish for trout or black bass before rendering his verdict. The sense of touch seems well developed. Numerous fishes have tactile barbels about the mouth, as the catfish, sturgeon, and codfish. The lateral line is considered a sense organ. There is an internal ear, but it does not appear that fishes hear ordinary sounds made out of water, like human speech, unless they are loud; on the other hand, fishes have a keen perception of any sound vibrations that are directly transmitted to the water, such as splashing in the water, noises made by the grating of oars in the oarlocks or by hard objects striking the bottom or sides of a boat. The semicircular canals are now understood to be connected with a sense of equilibrium. Smell is probably pretty well developed, in some fishes at least. The nostrils have nothing to do with respiration in any fishes below the lungfishes. The nostrils do not open into the mouth, but are simply openings into a cavity around which the nerves of smell are distributed. Some fishes have a single nostril on each side. In others, as in the perch, there are two openings on each side. The two nostrils of one side connect with a common cavity, the water entering through one aperture and leaving through the other. The sense of taste is probably less distinct.

Excretory Organs of the Perch. — The gills excrete carbon dioxid. For the removal of nitrogenous waste matter, there is a pair of slender red kidneys which extend the whole length of the body cavity. They can be seen through the dorsal wall of the air bladder. There is an enlargement at the anterior end in front of the air bladder. At the posterior end there is a tube, the ureter, to convey the excretion to the exterior; this duct joins a small urinary bladder and opens just back of the opening of the oviduct, so that the three openings at this place are, in order

from the front, the anus, the opening of the oviduct, and the opening of the ureter. In most of the higher fishes these three openings are separate.

Development of the Perch. — The ovary is an elongated body, occupying, when the eggs are mature, a large part of the space in the body cavity. The outlet of the ovary is the oviduct, whose external opening is just back of the anus. The ovary shows that it is really a double organ by its forked anterior end. In the male the two white spermaries unite in one sperm duct, which reaches the exterior just behind the anal opening. The eggs are fertilized after they have been laid. They are left without care on the part of the parents. The eggs contain a store of nourishment which is not yet completely absorbed when the tiny fish begins to swim. The young fishes feed at first on small crustaceans and other minute forms of life. Both the eggs and the young fishes are eaten in great numbers by many kinds of fishes and other voracious water animals.

Scales. — Scales are developments of the deeper skin or dermis, serving for protection, or ornament, or both. The scales usually overlap each other so much that only a small part of each scale is exposed, and this part is covered by the epidermis. The scales are usually of horny material and not bony, except in a few fishes, such as ganoids.

Kinds of Fish Tails. — When the tail is completely symmetrical, inside and outside, it is called diphycercal. In most fishes the tail, while externally symmetrical, is not so within, the spinal column being turned up as it joins the tail fin; such a tail is homocercal. When the tail is unsymmetrical, with the spinal column extending into the upper lobe, the tail is said to be heterocercal. It is noteworthy that the tails of nearly all young fishes are heterocercal.

The Fins. — The ordinary fin has a set of fanlike rays supported by a series of bones at the base of the fin. Fins are designated as "soft-rayed" or "spiny-rayed," according to the nature of the supporting rays.

The dorsal, anal, and caudal fins are called median, as they are in the middle plane of the body. The pectoral and pelvic are spoken of as "paired fins," and are comparable to the two pairs of limbs of the higher vertebrates.

Uses of the Different Fins. — As already noted, the tail fin is the chief propelling power. It also serves as a rudder in guiding the direction of movement. The paired fins serve as balancing organs and also serve in elevating or depressing the body. The dorsal and anal fins act like the keel of a boat in steadying and guiding the movement.

The Air Bladder. — The air bladder is generally considered as comparable with the lung of the higher forms. It certainly acts as an organ of respiration in the lungfishes and some of the ganoids.

But in most fishes the air bladder acts as an organ for maintaining the fish's position in the water, and hence is more appropriately spoken of as a "swim bladder." In the lungfishes and some ganoids the air bladder has a wide and direct connection with the gullet; in many other fishes the opening persists, but is less direct. On the other hand, in many fishes the duct is entirely closed. The air bladder may have thin walls or thick; it may be in one section or divided into several sections; it may be attached to the body wall or lie freely in the body cavity.

Flatfishes. — Fishes may be flattened in two ways: (1) from side to side, that is, laterally, when they are said to be "compressed," as in the ordinary fish, more markedly shown in the fresh-water sunfishes; (2) a fish that is flattened from above, or dorso-ventrally, is said to be

"depressed," as with the rays. The flounders are compressed, but have turned down on one side.

Electric Fishes. — These fishes have the power of giving an electric shock when touched. The electrical apparatus is a modification of the muscular system, and, like the muscles, is under the control of the nervous system. It is a point to be noted that the electric fishes are devoid of scales. The torpedo of the Atlantic coast and of the Mediterranean belongs to the rays. An African catfish has the same power, and in South America is found the electric eel. It is said that in South Africa the natives drive herds of horses into the pools, and after the electric eels have exhausted their "shocking power" on the horses, the eels may be caught and handled with impunity.

Colors of Fishes. — The colors of fishes are due to two factors, the nature of the scales and the pigment in the epidermis. The scales often are striated or polished to give various colors, especially the gleam so often seen on the sides of a fish. Aside from this kind of appearance the color is chiefly due to pigment. As in most animals, the color is darker on the back than below, where we often find white. The olive or dark back of most fishes makes it difficult to see them when looking down into the water, while the white color beneath might make a fish less conspicuous to an enemy below him. In the breeding season many fishes, especially the males, assume much brighter colors, most accented on the fins. Many fishes, notably catfishes, change their color considerably in conformity with their surroundings, like the amphibians and lizards.

Care of the Eggs and Young. — Most fishes give no care whatever to the eggs or young. Some deposit the eggs in a place of comparative safety. The stickleback builds a nest for the eggs and the male defends them carefully.

But the eggs of many fishes are eaten by thousands by many kinds of fishes and other animals. The very great number of eggs laid by most fishes is in keeping with the fact that the chances are many to one against their successful development. Indeed, if the eggs all developed, it is easy to see that the ocean would be overrun. For instance, the codfish is said to lay about eight million eggs yearly; if each of these eggs developed, it would not take long literally to fill the ocean. Contrast this "infant mortality" with that of the fulmar petrel. This is said to be the most numerous bird in the world, though it lays but a single egg; but the conditions are such that the chances of this single egg for reaching maturity are extremely favorable.

Migration of Fishes. — The salmon, shad, and sturgeon pass from the sea up rivers to spawn. The eels pass from rivers into the sea to lay their eggs. Aside from migrating to find suitable breeding grounds, fishes migrate more or less in search of food. With some kinds their movements are pretty regular and well known; in other cases their location at any given season is very uncertain, depending on their food and other conditions not accounted for.

Deep-sea Fishes. — Most fishes are found near shore or in comparatively shallow water. Of those found in deeper waters, it is interesting to observe that, as the water becomes deeper, and the amount of light consequently less, the fishes usually have larger eyes, or else a better development of the organs of touch. In the deepest water many are phosphorescent, and blind fishes, or fishes with rudimentary eyes, are found.

The Food Fishes. — Among the principal food fishes are the codfish, salmon, haddock, shad, mackerel, hake, smelt, sardine, menhaden, mullet, lake trout, whitefish, sturgeon,

halibut, flounder, herring, catfish, various kinds of bass, both fresh-water and marine, pike, pickerel, sucker, buffalo, carp, and many others. Space will not permit an account of them here, but the student is referred to the *Riverside Natural History*, and other works of the same scope.

Artificial Propagation and Distribution of Fishes. — In late years much has been done toward protecting and propagating our edible fishes. With the increase of population the food question will gradually become a more and more serious one. An excellent authority has said that an acre of water ought to supply as much food as an acre of land. The time has passed when the privilege is extended to any one to fish anywhere and at any time. Common sense dictates that fishes should not be caught during their breeding season, and that they should not be caught under a certain size, etc.; hence laws limiting the fishing season, and requiring that seines must have meshes not less than a given size. Killing fishes by the use of dynamite is prohibited. Also it is provided that there shall be no obstruction to the free passage of fishes up and down streams; and that where dams are necessary, side channels (fish ways) shall be provided.

Most of the states have enacted laws for the protection of its native fishes. A number of states have made appropriations for the establishment and maintenance of fish hatcheries, where fish are artificially hatched. These are shipped, to be introduced into various waters where it is thought they will thrive, sometimes to replenish a stock that is diminished by overfishing or other causes; in other cases to introduce them where they do not naturally occur. The United States government has also taken the matter in hand, and many valuable results have been obtained. This industry is comparatively in its infancy, but it promises

to increase greatly the world's food supply. It remains to be seen what can be done toward getting rid of the more voracious fishes that destroy so many of the young of the food fishes. The pikes, including the pickerel and mascalonge of the tributaries of the Mississippi and St. Lawrence, must greatly reduce the numbers of more valuable fishes. If they were to increase rapidly, they might nearly deplete the waters, so active and voracious are they.

CHAPTER XI.

BRANCH CHORDATA.

CLASS PISCES (*Continued*).

The Elasmobranchs.

THE sharks and rays are the chief representatives of the subclass designated Elasmobranchii. They are nearly all marine. One of the best representatives is the shark known as the "dogfish," which is caught in large numbers along the New England coast for the sake of the oil obtained from the livers. It differs from the "true fishes" in the following points: —

1. The skeleton is cartilaginous, never bony.
2. There is no gill cover, the gill slits (usually five) opening separately.
3. The mouth and nostrils open ventrally.
4. The scales are small and separate, making the skin rough.
5. The tail is heterocercal, — that is, the spinal column extends up into the upper lobe.
6. The eggs are few and large, inclosed in a tough case, the walls being strengthened by chitin. In some sharks, as the dogfish, the young are brought forth alive.
7. There is no air bladder.

The Sharks. — The typical shark has a spindle-shaped body, and is exceedingly active. The mouth is far back under the head instead of in front, as in most bony fishes

The gill openings are separate. The teeth are flat, three-cornered, and sharp. There is a constant succession of teeth, so that as those of the front row are lost, others take their place from behind. Though sharks are very voracious, it does not follow that they always attack human

FIG. 103. SHARK (DOGFISH).
Showing separate gill slits. Tail heterocercal.

beings. For instance, on the coast of North Carolina sharks are abundant and of large size; yet they do not attack man. This is probably because fishes are abundant and the sharks have an ample supply of food. But in some parts of the world sharks are exceedingly dangerous.

The Rays. — The skates and rays have a broad body, partly due to the merging of the body into the large, horizontally flattened pectoral fins. The body is usually

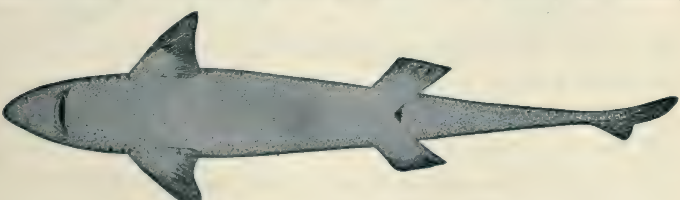


FIG. 104. SHARK (DOGFISH), VENTRAL VIEW.
Showing nostrils, mouth, gill slits, and anus.

rhomboidal, often wider than long. One form is called the "barn-door skate." They live on the bottom, feeding on mollusks, and have pavement teeth. Some have sharp

spines above the base of the tail, and are called "thornbacks" and "sting rays." Perhaps the largest of them is the "devilfish," sometimes attaining a width of eighteen feet and a weight of several tons.

Some of the rays have a complicated electric apparatus,

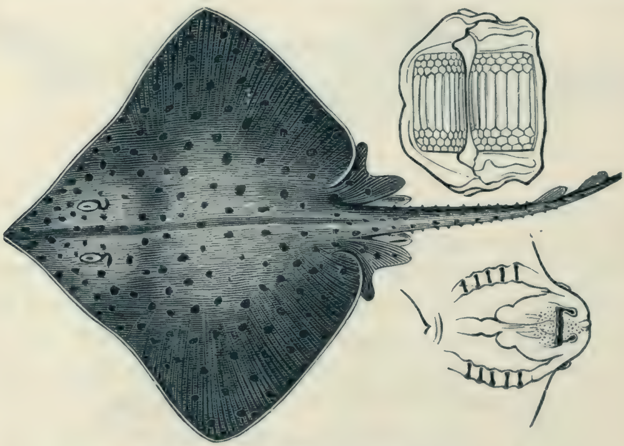


FIG. 105. COMMON SKATE (RAY).
Jaws and teeth (above); mouth and gill slits (below).
From Packard's *Zoölogy*.

with which they can give a strong shock to an animal with which they come in contact. This serves both as a means of defense and for securing prey. The one electric ray found on the Atlantic coast has the scientific name *Torpedo* and the common names "crampfish" and "numbfish."

THE BONY FISHES.

The great majority of fishes differ from the sharks and rays as follows: —

1. The skeleton is bony instead of cartilaginous.

2. The gills are protected by a gill cover, so that there is but one external opening.

3. The eggs are small and numerous.

The Spiny-rayed Fishes. — The perch is typical of a large group of fishes, all of which have spiny rays. The perch is widely distributed in fresh-water lakes and streams; the sea perch, or cunner, is common along the Atlantic coast, and is so nearly like the yellow or "ringed" perch that the descriptions and directions for dissection will apply fairly well to it.

In the same family with the perch is the pike perch, better known as the "wall-eye" or wall-eyed pike, an excellent food fish. Among the perches are also the darters, a most interesting family on account of their small size and peculiar habits. They rest on the bottom, never poising in the water like ordinary fishes; they are found in streams, in rapid currents, getting their food under

FIG. 106. MACKEREL.

stones, etc. They swim by means of their pectoral fins, coming to rest after the quick, darting motion that gives them their name. One species is only from an inch to an inch and a half long. Yet in some respects they are to be classed among the most highly developed of fishes. They may be caught in a minnow seine by taking pains to "keep the lead line down," that is, by being careful to drag very

close to the bottom. In keeping with the fact that they stay on the bottom is the fact that most of them lack an air bladder. They feed mostly on insect larvæ.

The sunfishes are a closely related family; these are well known as having short, deep bodies, usually with bright colors. More active than the sunfishes proper, though in the same family, is the black bass, so well known as a game fish. There are also the white bass, striped bass, and yellow bass in fresh waters, and various kinds of sea bass. Two important families of the spiny-rayed fishes are the mackerels and the codfishes.

FIG. 107. CODFISH.

Most of these fishes are very active and reckoned among the "game fishes" on account of their resistance to being caught and the skill required to capture them.

The Black Bass. — The black bass is probably more sought by the scientific angler than any other fish in the Central States. It is a fine type of the spiny-rayed fishes.

"The black bass is eminently an American fish; he has the faculty of asserting himself and making himself completely at home wherever placed. He is plucky, game, brave, unyielding to the last when hooked. He has the

arrowy rush and vigor of a trout, the untiring strength and bold leap of a salmon, while he has a system of fighting tactics peculiarly his own. I consider him, inch for inch and pound for pound, the gamest fish that swims." — J. A. HENSHALL.

The Catfishes. — The catfishes are scaleless; they have long, tapering barbels ("feelers") around the mouth; the mouth is wide, and the head low and flat, adapting the fish for a groveling life, skimming along the bottom. The dorsal and the pectoral fins each have for the first ray a very strong, stiff spine, with a jagged edge, by means of

FIG. 108. CATFISH; CHANNEL CAT.

which they inflict painful and probably poisonous wounds. They seem to be lovers of muddy streams, and lead a rather sluggish life. They abound in the Mississippi Valley, where some species reach a weight of 150 pounds. They are esteemed as food, as the flesh is of fair quality and unusually free from bones.

The Suckers. — In this family are a number of forms, such as the various suckers, the buffalo fishes, and carps, including some carps that have been introduced from Europe. The scales are large, with smooth borders; such scales are called cycloid scales. They all have a scaleless

head and a sucking mouth, toothless, with soft lips capable of downward extension; they feed to a large extent on vegetable matter, hence have a long intestine, in marked contrast with the short intestine of the carnivorous perch. The air bladder is large, and is constricted into two or three compartments, linked together sausagelike. The air bladder communicates with the digestive tube. They ascend streams in the spring to lay their eggs. Their flesh is rather tasteless and full of bones; still, they are largely used as food, as they cost less than other fishes, being caught in immense numbers in seines. Their sluggishness contrasts sharply with the alertness of the game fishes.

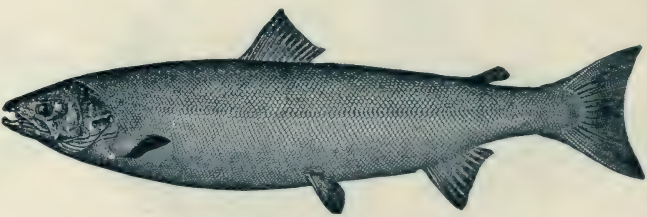


FIG. 109. ATLANTIC SALMON.
From Kingsley's *Zoölogy*.

The Salmon Family. — The salmon is well known both from its commercial importance and from its remarkable migrations up rivers to spawn. It passes swift rapids and leaps falls of considerable height. To this family also belong the trout and the whitefish of the great lakes.

The Trout. — One of the daintiest of fishes, as well as one of the most delicately flavored, is the trout. On account of its wariness it is sought by the angler who wishes to overmatch its cunning.

"This is the last generation of trout fishers. The children will not be able to find any. Already there are well-

trodden paths by every stream in Maine, in New York, and in Michigan. I know of but one river in North America by the side of which you will find no paper collar or other evidence of civilization. It is the Nameless River. Not that trout will cease to be. They will be hatched by machinery and raised in ponds, and fattened on chopped liver, and grow flabby and lose their spots. The trout of

FIG. 110. THE RAINBOW TROUT.
From Kellogg's *Zoölogy*.

the restaurant will not cease to be. He is no more like the trout of the wild river than the fat and songless rice bird is like the bobolink. Gross feeding and easy pond life enervate and deprave him. The trout that the children will know only by legend is the gold-sprinkled living arrow of the white water, able to zigzag up the cataract, able to loiter in the rapids, whose dainty meat is the glancing butterfly." — MYRON W. REED.

The Flatfishes. — As an example of this group we may select the flounder found along the Altantic coast. These fishes keep near the bottom, swimming on one side, and the two eyes are both on the side that is uppermost. Perhaps the most interesting fact concerning these odd fishes is their development. At first they are symmetrical, with

an eye on each side, and erect like other fishes; gradually the body turns over to one side, the cranium becomes twisted, and the eye of the side that turns down travels over to the upper side; the upper side becomes dark, while the under side is white or nearly so, whereas in the young flounder both sides were colored alike. The sole and the plaice belong to this family. The most important member,

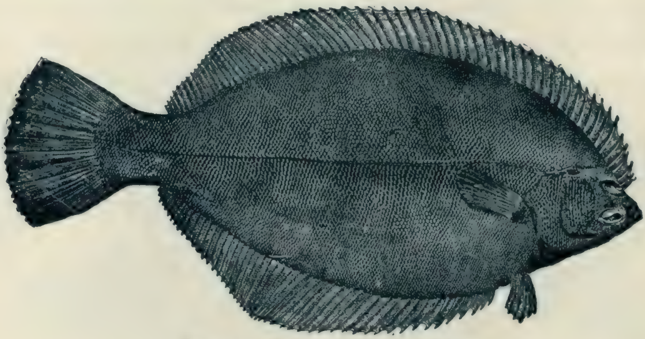


FIG. 111. WINTER FLOUNDER.
From Kingsley's *Zoölogy*.

however, is the halibut, which sometimes reaches a weight of three or four hundred pounds.

Eels. — The eels have elongated, cylindrical bodies, with minute scales or none. They have no ventral fins, and swim or crawl through the mud by a snakelike motion. They are active and very voracious, pushing their way under stones and into holes after small fishes and crustaceans, on which they feed. It is said that they can crawl a considerable distance on land, through wet grass, and that they pass around falls and other obstructions in this way.

Flying Fish. — Certain marine fishes are called "flying fishes." They do not really fly, but, by means of their long pectoral fins, make long flying leaps through the air. They

make these leaps better against the wind than in the same direction as the wind. Their leaps are probably somewhat like the "sailing" of birds.

THE GANOIDS.

We have in the United States four kinds of ganoids, the gar pike, the sturgeon, the mudfish, and the spoonbill catfish

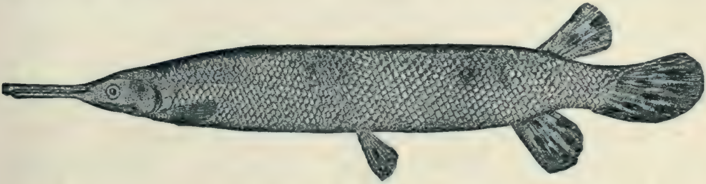


FIG. 112. GAR PIKE; GAR.

The gar pike has a cylindrical body covered by rhomboidal bony scales. These scales are coated with enamel, making a very strong and complete armor. The jaws extend, forming a long bony snout, the nostrils being at the tip of the upper jaw. The teeth are sharp, and the fish is voracious, but of rather sluggish habits. The tail is slightly heterocercal. Three species are common in the Mississippi and some of its tributaries: the long-nosed gar (Fig. 112); the short-nosed gar; and the alligator gar, which is said sometimes to attain a length of ten feet.

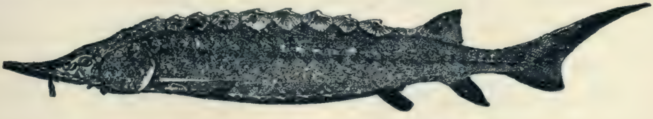


FIG. 113. COMMON STURGEON.
After Goode. — From Kingsley's *Zoölogy*.

The sturgeon is decidedly like a shark in general appearance, with its strongly heterocercal tail, its projecting snout, with the mouth well back on the ventral surface, and

its cartilaginous skeleton. The skin is also rough like that of a shark; but in addition to the separate scales that give roughness, there are several rows of bony plates, each with a central projecting point. These rows of scales are not set close together, one row of large scales being along the back, with rows of smaller scales along the sides. The sturgeon has a projectile toothless mouth, and feeds along the bottom, sucking up worms, larvæ, etc., from the mud.

The spoonbill catfish very much resembles a catfish, being smooth-skinned, but has a long, paddle-shaped upper jaw with which to stir up the mud from which it gets its food.

The mudfish, or bowfin, is, in the Mississippi Valley, commonly called the "dogfish," an unfortunate term that

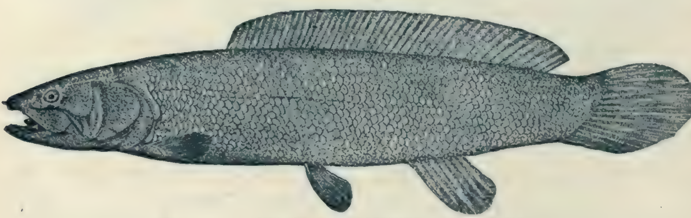


FIG. 114. MUDFISH; BOWFIN; GRINDLE.
Dogfish (of Central States, but should not be confused with the shark called dogfish).

is likely to confuse it with the shark called by the same name. The mudfish, as the name implies, lives in shallow water, and is a very voracious fish. It is more nearly like the ordinary bony fishes than the other ganoids, having a pretty complete bony skeleton. Its flesh is soft, and generally considered as wholly unfit for food, but of late it is beginning to be used. In some waters of the Mississippi system it is very abundant.

These four fishes do not present many characteristics in common, hence it is not strange that the authorities differ greatly as to their classification. In the first place, it should

be noted that there are but few living ganoids; these are the survivors of a host that existed in earlier geologic periods. Many of these fossil forms possess a heavy armor, of which the gar shows a sample. It is also noteworthy that North America has a majority of the survivors. Most of them have heterocercal tails.

The most valuable feature for our consideration is the air bladder, which is present in all, and in all is connected with the gullet by a persistent open duct. This duct opens on the dorsal side of the gullet except in one instance. Further, the air bladder in most has an unusual supply of blood, so that it serves to a considerable extent as a lung. Both the mudfish and the gar pike often come to the surface and emit bubbles and take in a fresh supply of air,

FIG. 115. LUNGFISH.
After Boas. — From Kingsley's *Zoölogy*.

very much as do the mud puppy and the tadpole after the lungs begin to develop. These two fishes are very tenacious of life when removed from the water, undoubtedly because of the ability of the air bladder to act as a lung. The ganoids thus foreshadow the lungfishes, as, in turn, the lungfishes anticipate the Amphibia.

THE LUNGFISHES.

In the lungfishes the development of the air bladder as a lung is much more complete than in any of the ganoids. The nostrils open into the mouth cavity, which is not the

case with any other fishes. There is also a pulmonary artery and a pulmonary vein, making the circulation much more perfect. In keeping with this, the auricle is partially divided into two compartments. There are only three or four species, one in Australia, one in Africa, and one or two in South America. The Australian form has a single lung; the others have the lungs double. The African lungfish secures protection during the dry season by burying itself in the mud, where it remains in a snugly inclosed cavity. These "mud nests," as they are called, have been dug up and the fish taken alive and uninjured to Europe. Gills are present and permanently kept.

It is a general belief among naturalists that the Amphibia originated from such lunged fishes as these we have been considering. Why, indeed, should we hesitate to believe that a race of animals has gradually changed from an aquatic to a terrestrial life in long course of time, when we have all seen this change take place in the individual frog in a relatively short time? Whether they were first led to do this from the drying up of the water or from pollution of the water, making it unfit for respiration, or whether they were forced to adopt a land life from the competition for a living in the water, or from some other causes or conditions, who shall say?

SUBCLASSES OF PISCES.

<table>
<tr><td rowspan="4">Class Pisces.</td><td>Subclass 1.</td><td colspan="2">Elasmobranchii, sharks and rays.</td></tr>
<tr><td rowspan="2">Subclass 2.</td><td rowspan="2">Teleostomi.</td><td>Teleostei, the bony fishes.</td></tr>
<tr><td>Ganoidei, "ganoids."</td></tr>
<tr><td>Subclass 3.</td><td colspan="2">Dipnoi, the lungfishes.</td></tr>
</table>

CHAPTER XII.

BRANCH CHORDATA.

CLASS AMPHIBIA.

Example. — The Frog.

Where Frogs Live. — Frogs are usually found in or near water. In the spring they congregate in ponds and pools to lay their eggs. Later in the season they scatter, and may be found at some distance from the water, but still in moist places, such as near springs, swampy meadows, etc. Even when they are spending most of the time in the water they come out on the banks to catch insects.

How the Frog Progresses. — The frog has three modes of locomotion — jumping, swimming, and creeping or walking. The latter mode is seldom used except to change its position or climb up something on which to rest. The long, muscular thighs enable the frog to make powerful leaps, by which it rapidly escapes to the water when it is on shore and alarmed. In swimming it folds the fore limbs alongside the body and by the simultaneous strokes of the two hind limbs, with the long, broad, webbed feet, makes rapid progress. It is a model swimmer.

The Frog's Food and Method of Eating. — The frog feeds chiefly on insects, though it also eats slugs, worms, and various kinds of larvæ. The writer has found the remains of a mouse in the stomach of the common frog, and in the stomach of a bullfrog a small bird entire; but these cases are exceptional. The frog catches insects — its main

food — by means of the tongue. The tongue is attached in front and free behind. Insects are caught by turning the tongue forward quickly, the sticky mucus with which the tongue is covered holding them securely. There are fine teeth on the upper jaw and the roof of the mouth, but these serve merely to hold the insect or slimy worm, while it is being swallowed, and are not used for masticating the food. The wide mouth narrows into the gullet, which is really wide, since the animals captured are swallowed

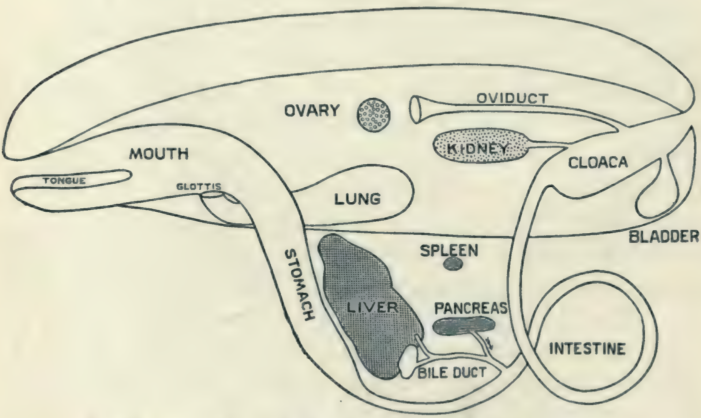


FIG. 116. PLAN OF FROG'S STRUCTURE, SIDE VIEW.

whole, but is kept closed by being "puckered up," as it were. Back of the gullet is the rather large stomach. The stomach narrows as it extends backwards, and is continued into the intestine, which, after one or two turns, suddenly widens into the cloaca. Alongside the stomach is the lobed liver; between two of the lobes is the bile sac, whose duct empties into the intestine a short distance behind the stomach. The duct from the small pancreas joins the bile duct a little before the latter enters the intestine.

How the Frog Breathes. — The adult frog breathes chiefly by means of lungs. In dissecting, the lungs may be found collapsed; in which case they are small and dark-colored. When inflated they are of considerable size and of a beautiful pinkish color, owing to the blood in the capillaries. A frog's lung is not a mere air sac, with transparent walls, as with most fishes. There is blood circulating in the wall, and the wall is somewhat thickened, and has ridges extending on the inside, which, to a limited extent, partition off the space into air vesicles, thus increasing the area of the inside of the lungs, and consequently exposing more blood to the action of the air contained within the lung.

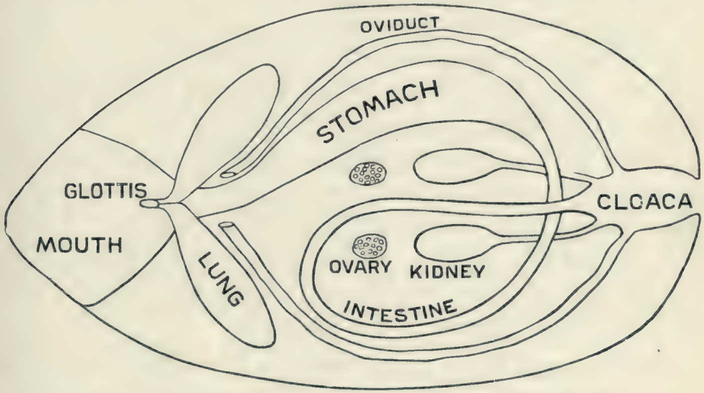


FIG. 117. PLAN OF FROG'S STRUCTURE, VENTRAL VIEW.

In watching the breathing movements of the frog, three actions are seen: first, the in-and-out movement of the floor of the mouth; second, occasional movements of the side of the body; third, opening and closing of the nostrils. When the floor of the mouth is lowered and the nostrils are opened, air is taken into the mouth cavity; if, now, the nostrils are closed and the floor of the mouth

raised, air is forced into the lungs. The gullet is kept firmly closed so that air does not enter it, and the glottis, a longitudinal slit in the floor of the mouth just back of the tongue, being opened at the right time, air freely enters the lungs. The windpipe, or trachea, is extremely short, dividing almost immediately to enter the two lungs. The less frequent movements of the sides of the body seem to be for driving air out. This is accomplished by the action of the muscles of the sides of the abdomen. From the above it may be understood why a frog may be suffocated by having its mouth held open for any considerable time.

The frog also breathes to a limited extent by means of the skin. It has been noticed that the skin is always moist, a condition necessary for this function. In cool weather it will be noticed that frogs kept in aquariums frequently sink to the bottom and remain there for a long time. Of course the breathing movements then cease. The diminished activity is accompanied by a reduced respiratory need, and the blood, circulating in the skin, absorbs all the oxygen that is required.

Circulation of Blood in the Frog. — The heart consists of one ventricle and two auricles. The right auricle receives blood through the caval veins from all parts of the body except the lungs; this blood is dark because it has been deprived of its oxygen by the working tissues of the body; it is loaded with impurities which the tissues have given to it. The left auricle receives blood from the lungs; this blood is bright-colored from the oxygen just obtained in the lungs; it has also lost some carbon dioxid.

The two auricles contract at the same time and send these two kinds of blood into one ventricle. How is one ventricle to send the purer blood to the organs that need it, and the impure blood to the organs whose work it is to

remove impurities? Without attempting here to explain this in detail, it may be stated that, owing to the way in which the arteries branch from the ventricle, and to an ingenious valve arrangement, (1) the best blood is sent to the head, (2) the next best blood (somewhat mixed) is sent to the body, and (3) the most impure to the lungs and skin.

The Lymphatic System. — In skinning the frog it is very noticeable that the skin is attached only occasionally, leaving a free space between the skin and muscles over the greater part of the body. In these spaces is a more or less watery liquid, the lymph. Lymph is also found in the body cavity around the internal organs. The lymph system is part of the blood system. Lymph may be described as part of the liquid of the blood that has soaked out of the regular blood tubes and gotten into the lymph spaces. There are two pairs of contractile "lymph hearts," one, whose pulsations may have been observed, near the anus. The other pair is between the transverse processes of the third and fourth vertebræ, and cannot readily be found.

Excretion of Impurities. — The lungs and skin remove carbon dioxid from the blood as it circulates through them. The nitrogenous waste matter is taken from the blood as it flows through the kidneys. From each kidney a tube called the ureter passes back to open into the cloaca on its dorsal surface.

The Colors of the Frog. — The prevailing colors are green and brown, though some are marked by black spots, and sometimes these black spots are made more distinct by a whitish border. The frog does not frequent bare ground, but is usually to be found near plants, whether in water or on land. Its colors are generally similar to the surroundings, so that it is not a very conspicuous object, and sometimes keen eyesight is needed to discover it even when in plain view. By distending its lungs the frog easily floats in water. When so floating only the top of the head is out of water, with its three projecting points, the snout and

the two eyes. In some kinds of frogs the head is more distinctly green than other parts, so a little practice is required before the collector readily discovers it as it rests in the water, with the top of the head appearing among green leaves.

The color is due to pigment cells in the deep layer of the skin. These cells are branched, but can change their shape and vary the color somewhat in accordance with the surroundings. These cells may easily be observed in the skin of the frog's web, and can hardly escape observation when the circulation in the web is studied.

The Frog's Enemies. — Most of the larger snakes eat frogs when they can get them. Many fishes take them greedily, hence the frog is used as bait. A number of birds capture frogs, including some of the hawks, certain waders, and perhaps others.

The frog's color undoubtedly often keeps it from being discovered, and when it is approached it can make use of one, or both, of its two speedy modes of locomotion to make good its escape; concealment by protective resemblance and escape by flight are its two safeguards, for it has no weapons of defense.

How Frogs spend the Winter. — At the approach of freezing weather frogs reassemble at the shore, and perhaps for some time may be found at the surface during the warmer part of the day, but stay at the bottom during the night or during colder days. They finally dive deep into the mud,— which is their winter resort. Here they hibernate, motionless, eyes closed, lungs emptied, with no breathing movements, the heart beating feebly and slowly, till they are revived by the returning warmth of spring.

Warm-blooded *vs.* Cold-blooded Animals. — The frog's normal temperature during the season when it is active is a

little above the surrounding air or water. Its temperature varies with the degree of its activity. In the winter when it is buried in the mud its temperature sinks nearly to the freezing point, for the lower layers of water have a temperature of about 40° F. In other words, the frog's temperature is *variable*, instead of constant as in the case of mammals.

The Nervous System of the Frog. — The widest part of the brain consists of the two optic lobes. In front of these are the two cerebral hemispheres. Barely separated from the anterior ends of the cerebral hemispheres by a slight groove are the olfactory lobes; they seem to be a part of the cerebral hemispheres. Back of the optic lobes, separated by a depression, is the cerebellum, a narrow transverse band. Beyond the cerebellum is the spinal bulb (see also Fig. 167). There are ten pairs of cranial nerves. There are also ten pairs of spinal nerves.

The Senses and Sense Organs of the Frog. — The prominence of the frog's eyes has already been noticed. The upper lid is thick and drops with the eye when it is withdrawn. The thin under lid can be drawn more completely over the eye and is often used when the upper lid remains stationary. Back of the eye the eardrum is conspicuous. From the inner surface of the tympanum extends the bony rod called the "columella" to the inner ear, to which it transmits the vibrations received by the tympanum. The sense of taste is apparently well developed. All parts of the skin seem to possess the sense of touch. The nostrils open directly into the front of the mouth. Of the sense of smell less is known than of the other senses.

Development of the Frog. — The eggs are formed in the ovaries. When the eggs are mature the ovaries become much folded and plaited and the egg-masses occupy a large

share of the space in the body cavity. The eggs finally are set free in the body cavity; they find their way to the open-

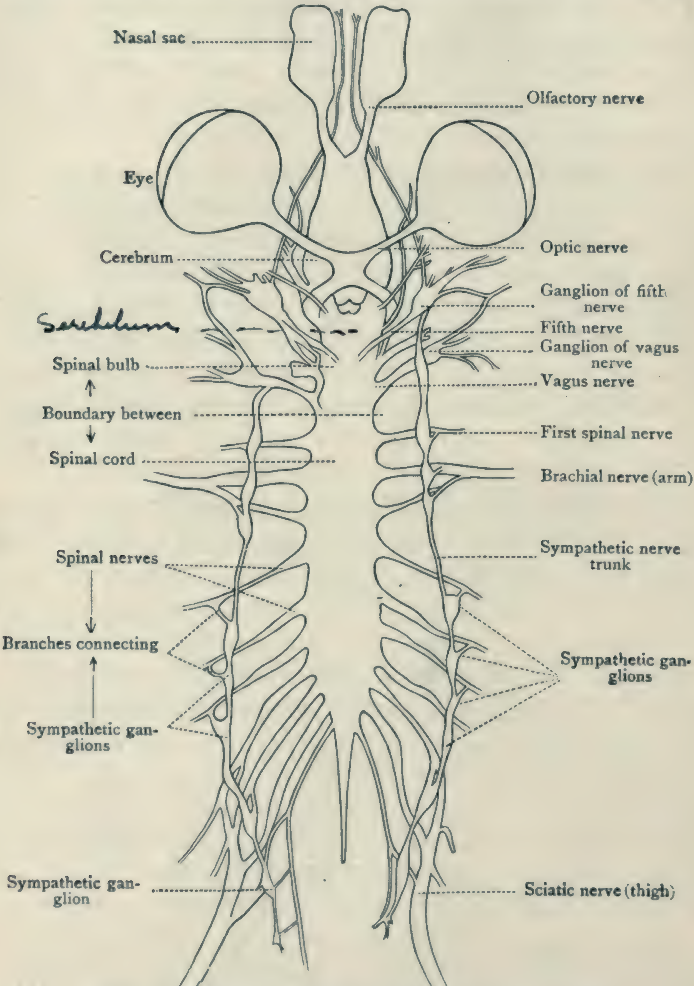


FIG. 118. NERVOUS SYSTEM OF FROG, VENTRAL VIEW.

ing at the inner end of the oviduct and as they pass along the duct are coated with a layer of gelatinous material which swells up after the eggs are laid, so that each egg appears as a small, spherical, glassy body, with its upper part of a dark color, and surrounded by a spherical mass of clear, jellylike substance. In a few weeks the form of the body begins to appear. The tail begins to vibrate, the surrounding mucus breaks up and the tadpole emerges with gills — very much like a tiny fish. For a short time there is no mouth opening, and the little tadpole attaches itself to waterweeds by suckers near the place where the mouth is to

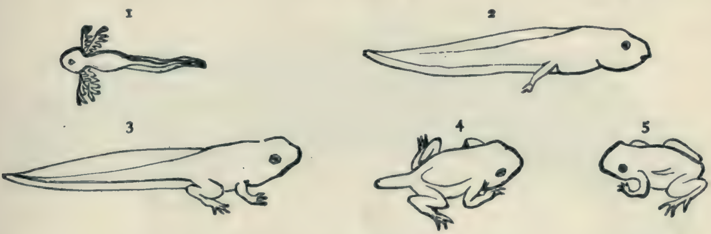


FIG. 119. DEVELOPMENT OF A TOAD.
From Packard's *Zoölogy*.

appear. After the mouth, with horny lips and jaws, is developed, the tadpole feeds greedily on waterweeds and grows rapidly. The external gills disappear and are replaced by internal gills, which are concealed by a fold of skin which incloses a gill chamber. There is an opening on the left side of the body for the water to escape. The limbs develop as little projections, like buds, on the sides of the body; but the anterior limbs are for a long time concealed by the gill chamber and therefore appear to develop later than the hinder pair. At first the tadpole swims, fishlike, wholly by means of the tail, and it continues to do so long after the limbs appear. It holds the limbs close by the side

of the body and swims by the sidewise movements of the tail. At this time the intestine is long and coiled spirally. Then for a time the tadpole quits eating. It fasts, but is maintained by the material from its tail, which is being absorbed while a great transformation is taking place. The horny lips and jaws are shed, the mouth becomes wider and develops true jaws with teeth. The long, coiled intestine becomes relatively short. The anterior limbs are pushed out through the fold of the skin that inclosed them. Lungs are developed, although they are at first but little used, the tadpole coming to the surface occasionally to get a mouthful of air; respiration is still chiefly accomplished by the

FIG. 120. THE SIREN; MUD EEL.
Gills persistent.

gills, but the lungs come to be used more and the gills less until finally the gills disappear. It was herbivorous; now it is carnivorous. Formerly strictly aquatic, it is now amphibian. In short, our tadpole has become a frog.

CLASSIFICATION OF AMPHIBIA.

The Siren. — The lowest of the amphibians is the siren or mud eel. It is eel-like in form, having gills that persist through life, and one pair of legs (the anterior). It lives in the swamps of the Southern states and sometimes is three feet long.

The Mud Puppy. — The mud puppy, or water dog, is a little higher than the siren, having two pairs of legs. It also has persistent external gills. It is found in the streams

FIG. 121. NECTURUS; MUD PUPPY (NORTH); WATER DOG (SOUTH).
Gills retained thruout life.

of the Mississippi Valley and in the lakes of central New York. It sometimes attains a length of two feet.

FIG. 122. SPOTTED SALAMANDER.

The Salamanders. — The salamanders are still a step higher. They have gills in the earlier stage, but shed them when adult. They retain the tail, and, in swimming, fold

the two pairs of limbs close to the body and swim by lateral movements of the vertically flattened tail. Most of the salamanders live on land, but they seek moist places. The salamanders are often incorrectly called lizards. They are pretty well distributed in temperate and tropical regions. Most of them are of rather small size. One form is used as food by the Mexicans. In some forms the larva is larger than the adult. In unfavorable conditions some of the larvæ fail to transform, but permanently, or at least indefinitely, retain the gills. Some European forms fail to develop lungs. Many of the salamanders reproduce the legs or tail when these members have been lost. Like the other amphibians, the salamanders go to the water to lay their eggs, and all salamanders, whether they lead a terrestrial life later or not, spend their early life in the water, breathing by means of gills. One family of salamanders are called newts or efts. None of our amphibians are in any way poisonous or injurious to man, though several of them are reputed to be so.

Frogs and Toads. — These are the highest of the amphibians. They have lost, not only the gills, but also the tail. They are not only fitted to live a truly terrestrial life, like the salamanders, but are much more active than the latter, having the hind limbs well developed for leaping, whereas the two pairs of limbs in the salamander are nearly equal, and it can, at best, only crawl.

One of the commonest of the frogs is the leopard frog, so named from its spots. Quite similar to it in general appearance is the pickerel frog. The green frog is greenish and brownish, with small dark spots. The bullfrog is well known from its size and heavy voice.

The common toad has a rough-looking, warty skin, in which are glands that secrete an irritating liquid for pro-

tection. The toes are webbed, but not so completely as in the frog. The hind limbs are less fully developed, and so the toad merely hops, instead of jumping like the frog. The frog has teeth in the upper jaw only, the toad in neither jaw. The toad lives away from the water; still it goes to the water to lay its eggs, and the young tadpoles pass through the same stages of development as the frog. The toad lays its eggs in strings, while those of the frog are in masses. The tadpoles of the toad are usually darker than those of the frog. The toad has the same kind of tongue as the frog and catches insects in the same way. The toad is usually of a duller color, corresponding with its surroundings.

The tree toads or tree frogs are somewhat warty and thus get the name "toads," but they are in a different family from either frogs or toads. They are peculiar in having the tips of the fingers and toes dilated into disks, which adhere and thus aid in climbing. No matter how high and dry they may live in trees, they return to the water to lay their eggs. As is well known, they can change their color through a considerable range, from nearly white to nearly black, in keeping with the surface on which they are resting. The hind limbs are elongated as in other frogs, but, since they jump little, if any, the muscles of these limbs are slightly developed, making them slender instead of strong and muscular.

Though the larynx is poorly developed, nearly all the frogs and toads have voices. The males have louder voices, and most of these are well known, from the faint "peep" of the little frogs and the shrill "trill" of the tree toad to the heavy bass notes of the bullfrog.

Some Peculiar Forms of Development. — In some of the islands of the ocean where there are no marshes, the development is direct, the

young being hatched in the form of the adult. A few forms bring forth the young alive.

CHARACTERISTICS OF AMPHIBIA.

The Amphibia breathe by gills in the larval state, but generally develop lungs in becoming adult. They have no fin rays as with the fishes, but usually have paired limbs with distinct fingers and toes.

Aquatic Life *vs.* Terrestrial Life. — Several lines of investigation converge to prove that at one time the globe was entirely covered by water. Of course until there was land there could be no land life. What were the first forms of life on the land ? Did some of the forms of aquatic animals gradually become fitted for living on land and then desert the water ?

The study of the amphibia seems to throw some light on these questions. In the ganoid fishes we saw that the swim bladder had some circulation of blood in its walls and that there was an opening from the gullet into the swim bladder, which is, in action at least, a sort of rudimentary lung. The lungfishes have the air bladder still more completely developed as a lung. The lungfishes came to the very door of land life, but remained aquatic. The Amphibia boldly stepped over the threshold and were, probably, among the first of the animal kingdom to emerge from the water to live upon the land. This transition from life in the water to life upon the land marks a great step upward. Perhaps it would be hard to believe that any group of animals had made such a profound change, if it were not for the fact that we see this same change in the individual life of every amphibian.

Gradation among the Amphibia. — It is interesting and instructive to observe the successive progress in the various groups of amphibians. If we consider in succession the siren, mud puppy, salamander, and frog, we see that they all have traveled along the same road, only some have gone farther than others. They all start as limbless tadpoles, with gills, practically in the same stage of development as the fishes. The siren develops one pair of legs, retains the legs and gills, although developing lungs, and goes no farther. The mud puppy makes a slight advance by developing another pair of legs. It retains the two pairs of legs and the gills, at the same time breathing, in part, by means of lungs. The salamander takes a decided step upward when it sheds the gills and

breathes by means of lungs. The frog goes through all these stages, but rises to a still higher level by getting rid of the tail which it had in its larval life. In short, each of these forms has gone through all the stages represented by the forms below it in the scale, but has discarded certain features and has advanced to a higher plane and leads a more active life.

The life history of the frog, therefore, serves to review all the other forms of amphibians below it in the scale. The temporary stages of the frog's life represent the permanent form of the lower kinds of Amphibia. To put it in another way, — they all start at the foot of the same stairs at the fish level, so to speak; the siren climbs up on the first step and stops there; the mud puppy makes one more step and rests content; the salamander mounts still higher by a step and has reached its highest point; while the frog takes all of these steps and reaches out once again and tops the series by getting on the highest step of the stairs.

This series illustrates a law which, though general, does not appear so clear in some other groups. The stages of development of the individuals of the higher groups recapitulate the development of the group as a whole; or, in other words, "the development of the individual epitomizes the development of the race."

DIFFERENCES BETWEEN FISHES AND AMPHIBIANS.

Fishes.		Amphibians.
Persist through life	Gills	May disappear in adult
Air bladder respiratory in lungfishes	Lungs	Present in adult
1 Auricle, 1 Ventricle	Heart	2 Auricles, 1 Ventricle
Fins with fin rays	Limbs	Limbs with digits
Scales (usually)	Exoskeleton	Skin smooth (usually)
Not open to mouth (except lungfish)	Nostrils	Open into mouth

ORDERS OF AMPHIBIA.

Class Amphibia	Order 1.	Urodela	Salamander
	Order 2.	Anura	Frog
	Order 3.	Gymnophiona	Blind-snake

CHAPTER XIII.

BRANCH CHORDATA.

CLASS REPTILIA.

THERE are four principal forms of reptiles, represented by the lizard, snake, turtle, and alligator.

THE LIZARDS.

General Characters of Lizards. — Lizards are scaly reptiles, having, in the typical forms, two pairs of limbs and an elongated body, with a long, tapering tail, frequently twice as long as the rest of the body. The middle of each vertebra of the tail has a thin layer of cartilage, at which places the tail easily breaks off. The advantage of this arrangement is readily seen. When attacked by an enemy the chances are the lizard will be seized by the tail, for he is probably trying to escape by flight. The brittle tail breaks off, and as this constitutes the greater part of the length, the pursuer thinks he has the main part; at any rate, while he is holding this the curtailed lizard may make good his escape. But the tail grows out again.

In capturing lizards, which often lie basking in the sun, it is best to creep stealthily upon them till within arm's length, and quickly dart the hand forward. Unfortunately, in thus grasping them, the tail is in most cases broken off.

There are five toes, with claws, on each foot. There are no external ears, but the tympanum is sunken, leaving

a depression back of the eye. The eyes have movable upper and lower lids. The teeth are attached to the ridge or edge of the jaws, and are not set in sockets.

Lizards feed on insects, worms, and other small animals, though a few forms are herbivorous.

Lizards are active in habits, some being called "swifts." They are found on the ground, more often in sandy soils, on rocks, trees, walls, etc., being most abundant in warm countries. There are not many north of latitude 40°. A few live more or less in the water, but they do not have gills at any stage of their lives.

FIG. 123. GREEN LIZARD.
From Kingsley's *Comparative Zoölogy.*

Lizards lay eggs of comparatively large size, which are covered by a tough leathery or limy shell.

Many lizards are brilliantly colored, and some have power to change their color; most noted of these are the chameleon, of the old world, and the Anolis (Fig. 123), found in the Carolinas and Florida, which readily changes from a bright green to a dull brown according to its surroundings. Put one of these fellows in a box with a lot of dead pine needles, and note the color change. This lizard is often sold under the name "chameleon."

The Chameleon.—The true chameleon is found in Africa. Its power to change its color has been mentioned. It has a laterally compressed body, with a prehensile tail. Its feet are fitted for climbing by having two toes on one side and three on the other. The two eyes can move independently of each other, and the tongue can be darted out four or five inches after insects.

The Horned Toad.—This is a lizard with a broad, relatively short body, with spines on the back of the head. It is found in the dry regions of the Western and Southwestern states.

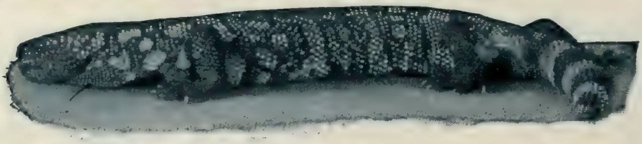


FIG. 124. THE GILA MONSTER.
The only poisonous lizard.—From Kellogg's *Zoölogy*.

The "Gila Monster."—This is the largest of the lizards found in the United States, being about eighteen inches long. It is found from New Mexico south and west. It is brown, with red markings. Its bite is poisonous, though seldom fatal to man.

The Iguanas.—In Central and South America and the West Indies are found the lizards called iguanas. They are about three feet long, and are found on the lower branches of trees. They are used as a food by the natives, and are said to be excellent eating.

The Monitors.—The monitors are found in Africa, Australia, and the East Indies. They are the largest of living lizards, being five or six feet long.

Differences between a Salamander and a Lizard.—Salamanders are commonly called lizards. The two animals have a general resemblance in form, both having elongated bodies, with two pairs of limbs and a long tail. The following tabular statement shows important points of difference:—

SALAMANDER (Amphibian).		LIZARD (Reptile).
Smooth	Skin	Scaly
Unarmed	Toes	With claws
Present in young	Gills	No gills at any stage
A metamorphosis	Development	Young like adult

The Joint-snake. — Every one has heard of the glass-snake or joint-snake, which is by no means rare in the Central states. The commonly accepted story is that when struck it flies to pieces, and that the pieces come together again, making the animal whole as before. The facts are as follows: The glass snake is a lizard without legs, and with a tail two or three times as long as the body proper; hence it looks very much like a snake. A closer examination would show that it can shut its eyes, which no snake can do. There is also a depression marking the ear, not found in snakes. A groove along each side of the body is also a feature never found in snakes. The tail is very brittle, as in all lizards. When struck, the tail is easily broken off and broken into several pieces, the short body usually crawling quickly away. No part of the tail lives. The disappearance of the pieces of the tail is easily accounted for by any one who knows how many animals are on the lookout for something to eat. To one who knows the animal's structure an explanation is easy; it is also easy to comprehend how the ignorant usually accept the popular story. If one can be obtained, carefully compare it with a snake.

THE SNAKES.

Characteristics of Snakes. — The absence of limbs is not distinctive, since the glass-snake is a legless lizard, and some snakes have rudiments of hind limbs. In snakes there are no movable eyelids, the eyes being covered by the thin, transparent epidermis. The mouth is very dilatable, the lower jaw being held by extensible ligaments, and the two halves of the lower jaw are also loosely connected so they can be stretched apart during swallowing. The tongue is long, soft, cylindric, and forked at the tip; it serves as an organ of touch, and has nothing to do with the poison apparatus. The teeth are relatively small, pointed backward, and serve to hold the prey and to aid in swallowing. There is no breastbone. The number of vertebræ is great, in the boa over four hundred. Ribs begin on the second vertebra and continue the whole length of the body cavity.

Locomotion of Snakes. — The chief mode of locomotion in a sinuous line is so well known that a double curve is designated as "serpentine." It should first be noted that along the whole length of the ventral surface is a series of broad, overlapping plates, — the scutes or ventral plates. By means of these the snake "gets hold" of rough places, for on a perfectly smooth surface it can make no progress. By the winding, wavelike motion of its body it both pulls and pushes itself along. The absence of limbs enables it to glide through grass and weeds and into crevices and holes. Snakes also glide along with the body straight. This is accomplished by rhythmically drawing the ribs and scutes forward and pushing them backward, or, as some express it, by "walking on the ribs."

Food of Snakes. — Snakes are carnivorous and take only living prey. This they swallow whole. The constrictors wind the body around the victim and crush it. Our common black snake (blue racer) is a good example of a constrictor. Our commoner snakes feed on toads, frogs, birds, etc. Garter snakes sometimes eat earthworms. Water snakes catch fish, frogs, and other aquatic animals.

Process of Swallowing. — Birds are usually swallowed head first. If the snake catches a frog by a hind leg, that part leads the way in. The backward-pointing teeth prevent escape. The two halves of the lower jaw are alternately pushed forward and drawn backward, and the victim is thus slowly drawn in. Meanwhile the salivary glands lubricate the object.

The Organs of Digestion. — The gullet is as wide as the mouth, and there is no constriction or line of demarcation between it and the stomach. The posterior end of the stomach is glandular. About halfway back in the body

cavity the stomach ends and is continued into the intestine, which pursues nearly a straight course. Near the posterior part of the body cavity it widens, forming the cloaca. Alongside the stomach is the long, narrow liver; from its hinder end the bile duct extends back to the bile sac, and from this a duct empties into the intestine a little way back of the stomach. The pancreas, a pale, roundish organ, also pours its secretion through a duct into the intestine. Digestion is a slow process, as might be guessed from the condition in which the food is swallowed, and the snake lies stupid and inactive for a long time after such a "bolted" meal.

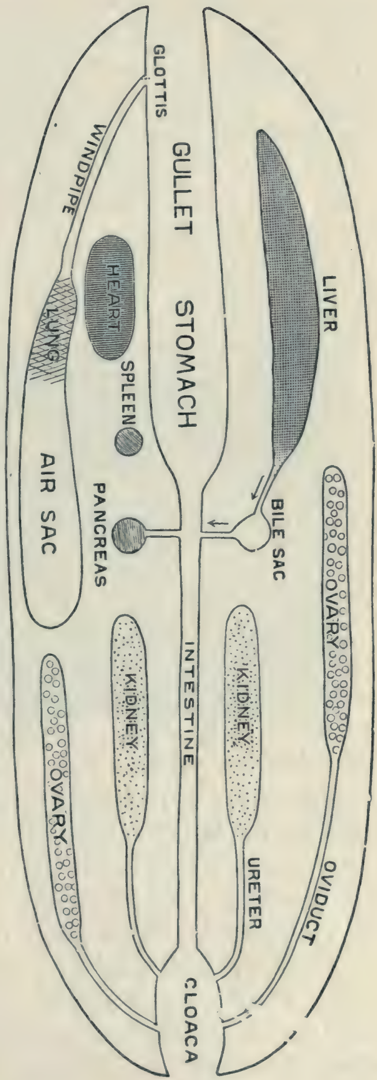


FIG. 125. PLAN OF INTERNAL ANATOMY OF A SNAKE.

How the Snake Breathes. — The right lung is long and nar-

row, and continues back, as a transparent air sac, through most of the length of the body cavity. The left lung is rudimentary, sometimes being so small it is difficult to see. The windpipe is long, beginning very close to the front of the floor of the mouth. This is regarded as an adaptation to the mode of eating, so that the snake may not be suffocated during the long and tedious process of swallowing.

Circulatory System. — The heart beat is slow and the circulation not very active. The heart continues to beat long after the head is severed. The temperature of the blood varies with that of the surroundings.

Excretory Organs. — In the posterior part of the body cavity are the two long, slender kidneys, whose ducts open into the cloaca.

The Eggs and the Young. — Eggs are produced in two long, narrow ovaries; the oviducts also open into the cloaca. Some snakes deposit their eggs in the earth, though probably a majority bring forth the young alive.

Senses of Snakes. — Sight and touch are fairly well developed, though a study of snakes does not reveal a keen sense of sight. Some snakes are affected by music, showing a sense of hearing. Of their senses of smell and taste we know but little.

Adaptations of Internal Organs to External Form. — We have seen how the external form is adapted to the mode of life. Let us now see how the internal organs are fitted to the necessarily long, narrow space allotted to them. In the first place the body cavity is so long that a moderately long digestive tube is accommodated without the necessity of coiling it, as in many animals. But one lung is developed, and that one is long and narrow, whereas our bodies admit of two relatively wide lungs placed side by side. The liver

is long and slender, and its bile sac is behind it. Not only are the ovaries (and spermaries) and kidneys slender, but they are not directly opposite each other; in short, everything is arranged on the tandem plan. Yet the snake is bilaterally symmetrical, in its fundamental plan, like other vertebrates and the vast majority of animals.

Poisonous Snakes. — Some of the front upper teeth of these snakes, called "fangs," are especially adapted for introducing poison. They are longer than the other teeth,

FIG. 126. — DIAMOND RATTLESNAKE.
From photograph by W. H. Fisher. — From *Recreation*, by permission of G. O. Shields.

can usually be erected or folded back, and have a hollow, or groove, by which poison passes from the poison sac into the wound by muscular pressure on the sac. The poison gland is a modified form of salivary gland. This poison is not a stomach poison, but a violent blood poison. Our chief poisonous snakes are the rattlesnake, now becoming rare in all thickly settled regions, the copperhead, and the water moccasin of the South. Their abundance and the danger from them are both grossly exaggerated. As an

antidote, a hypodermic injection of permanganate of potash (1 to 100), is by many now preferred to alcoholic liquor. In India the cobra kills several thousand persons yearly.

(See *The American Natural History.* Hornaday.)

How Snakes protect Themselves. — (1) By their color, (2) by flight, (3) by their odor, (4) by their poison.

Many snakes are colored so like their surroundings as to be decidedly inconspicuous, and this is of advantage both in escaping enemies and in securing their prey. By their noiseless mode of locomotion they can, unobserved, approach a victim or elude a pursuer. We are so familiar with their stealthy movements that we are not surprised when we learn that the words snake and sneak are of the same origin; nor do we wonder that there has been a long-standing enmity between man and serpent. Yet the majority of snakes are entirely harmless, and are as much surprised as we are when we "meet by chance." Many snakes have a disagreeable odor which probably serves to protect them from some enemies. Lastly, the poisonous snakes use their poison to secure food and to protect themselves. Among the enemies of snakes are to be reckoned several kinds of birds, such as the shrikes and hawks, hogs, wild and domesticated, bears (occasionally), and various other animals.

FIG. 127. DISSECTION OF HEAD OF RATTLESNAKE.

Showing fangs and poison sac (*p*). — From Kingsley's *Comparative Zoölogy.*

Molting. — At least once a year snakes shed the epidermis over the entire body, even over the eyes. During this process they are dull-colored and inactive.

DIFFERENCES BETWEEN A SNAKE AND A "GLASS SNAKE."

Snake.		Glass Snake.
No lids	Eyes	Movable lids
Dilatable	Mouth	Not dilatable
Extensible	Tongue	Not extensible
Invisible externally	Ear	Visible externally
Broad plates	Ventral scales	Small
Short, strong	Tail	Long, brittle
Absent	Lateral groove	Present

THE TURTLES.

General Characters of Turtles. — In turtles the relatively short and broad body is inclosed between two bony shields, the dorsal one being called the carapace, and the ventral, the plastron. The carapace is made up of (1) the widened spines of the thoracic vertebræ, (2) the ribs, which have widened and grown together, and (3) a series of marginal plates. There is no breastbone, but the plastron is made of a set of bony plates. Both carapace and plastron are covered by a set of horny, epidermal scales which do not coincide with the underlying bony plates. The "tortoise shell" of commerce is made of the epidermal plates of the big sea turtle known as the hawkbill turtle.

There are no teeth, but instead the jaws are horny. The neck and tail are the only movable parts of the spinal column, and these, with the legs, can be withdrawn so as to be protected by the shell. In the boxshell turtle there is a hinge in the plastron to make the protection more complete by closing the shell. The sea turtles have paddles, while the land turtles have feet, with more or less distinct toes. Some of the sea turtles weigh as high as a thousand pounds. The green turtles, so valued for soup, are caught in the West Indies at night, when they come

ashore to lay their eggs. Among the more noticeable of our inland turtles are the fierce snapping turtle, the soft-shell turtle, and the "gopher" of the South, which burrows in the ground. The terrapins of Chesapeake Bay are noted for their quality as food. All turtles bury their eggs, and our northern forms all hibernate in the mud.

THE ALLIGATORS.

General Features. — The alligators and crocodiles are like lizards in general form, but differ from them in several important points. They swim well by means of the vertically flattened tail. The skin is covered with horny scales, those of the back having corresponding underlying bony plates. The teeth of alligators are set in sockets, which is true of no animals below it in scale. The heart is also more complete than in the other reptiles, having a complete partition separating the ventricle into two parts. The temperature is about that of the surrounding air or water. The brain, though more highly developed than in other reptiles, is small relative to the size of the body and the skull. The alligators have a muscular, gizzardlike stomach. The young feed on fishes and small animals, but the full-grown alligators seize mammals, for which they lie in wait at the edge of the water until the animals come down to drink or swim. The nostrils, eyes, and ears are at the top of the head, so these reptiles can lie concealed, with their main sense organs extending into the air to discover their prey; they very much resemble a stranded log. The nostrils can be closed by a valve, which is done when a victim is dragged under water to drown. Alligators dig holes in the banks, in which they lay their eggs, which are sometimes as large as those of a goose.

The alligators of our Southern states grow to a length of

ten or twelve feet. Alligators are confined to the western hemisphere, occurring in the Southern states, Central and South America.

Crocodiles are found in both the old world and the new. One species is found in southern Florida.

Extinct Reptiles. — In earlier geologic ages reptiles were very much more numerous than at present. Not only were they more abundant, but there were more kinds; and many of them were large, some being eighty feet in length. Some were lizardlike, with long, slender necks. Others were fishlike. Some had resemblances to birds. The tracks of many of these ancient reptiles in the mud have hardened into rock, and have often been called "fossil bird tracks." Perhaps the most remarkable were the flying reptiles. They are supposed to have been rather batlike in appearance. The remains of these reptiles are found in rocks in many parts of the world, and the age in which they were most prevalent is called by geologists the "Age of Reptiles."

General Characteristics of Reptilia. — Reptiles are cold-blooded vertebrates, covered with scales, and when toes are present they end in claws. There is no metamorphosis after leaving the egg. There are no gills at any stage of life. Reptiles produce large eggs which are covered by a tough limy or leathery shell. Some reptiles are ovo-viviparous. Reptiles show a decided advance beyond amphibians in the development of the nervous system; in the respiratory system, since they breathe by lungs after leaving the egg; and in the circulatory system, the heart of the alligator having four cavities, as in birds and mammals.

CLASSIFICATION OF REPTILIA.

- Class Reptilia.
  - Order 1. Squamata.
    - Lacertilia — lizards.
    - Ophidia — snakes.
  - Order 2. Chelonia — turtles.
  - Order 3. Crocodilia — alligators.

CHAPTER XIV.

BRANCH CHORDATA.

CLASS AVES.

Example. — The Common Pigeon.

Adaptation for Flight. — The pigeon is fitted for flying: (1) by the wings, which, with their wide, strong, yet elastic feathers, are air paddles of marvellous efficiency; (2) by the powerful breast muscles which move the wings; (3) by the lightness of the skeleton; (4) by the air sacs throughout the body, which render it more buoyant; (5) and, not least, by the shape, being double pointed, so as to penetrate the air with the least resistance.

Structure of a Feather. — Let us consider the structure of one of the quill feathers. It consists primarily of two parts, the shaft and the vane, or flattened part. The shaft is solid so far as the vane extends, but the basal part is hollow, and is called the quill. The two sides of the vane are unequal in width, and the feathers overlap so that the wider side of the vane is beneath. The vane is made up of side branches called barbs, arranged in a close row. From each side of each barb arise secondary branches, called barbules; and the barbules of adjacent barbs interlock by little hooked ends, so that the whole vane is firm.

Feathers are developed from papillæ of the skin. In a growing feather it can be seen that the quill is full of pulp supplied with blood. In the fully developed feather the

dry, pithy remains of this pulp are found in the quill, which is now narrowed at the base, but still shows an aperture.

Kinds of Feathers. — There are four principal kinds of feathers: (1) The *quills* found on the wings and tail. (2) The *contour feathers*, which have the same general structure as the quills, but are smaller, and lie close to the body. They protect the body from bruises, and also from cold, being the very best of non-conductors of heat. Their mode of overlapping serves admirably for shedding rain and for retaining the heat when flying through cold air. (3) *Downy feathers*, which differ from the above in not having the barbs fastened together by hooked barbules; the result is a loose, soft feather, well suited for retaining heat. These feathers, when present, are inside the contour feathers, where we should expect to find them. The young pigeon has downy feathers, but they disappear in the adult. (4) The *pinfeathers* are fine, hairlike feathers, usually left after the pigeon is plucked, and usually removed from fowls by singeing. They show that they are feathers by a little tuft of barbs at the tip.

Distribution of Feathers. — Feathers are not evenly distributed over the surface of the body; but there are certain areas from which they grow, and certain other areas from which feathers never grow. By separating the feathers on a bird's breast it may readily be seen that no feathers develop there. There are also bare places on the sides of the neck and in other places; but the length of the feathers and their mode of overlapping cover these bare spots, so that most people hardly know of their existence.

The Pigeon's Wing. — The wing, like our arm, consists of three parts, the arm, forearm, and hand. The similarity of the first and second of these to the corresponding part of our arms is so evident that it needs no explanation. The

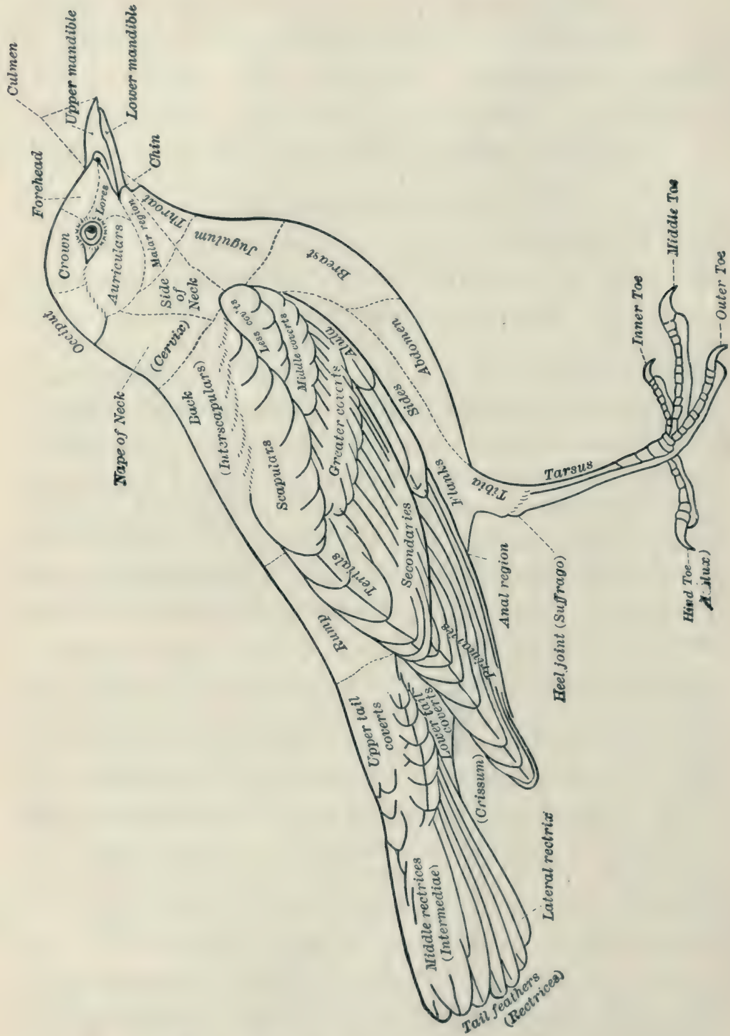


FIG. 128. EXTERNAL FEATURES OF A BIRD.

From Kellogg's *Zoölogy*.

front angle of the wing, or "bend of the wing," as it is called, corresponds to our wrist; but the hand is sharply bent back upon the forearm when the wing is folded, a position we cannot assume. When the wing is folded, the arm, forearm, and hand lie alongside of each other like this, z. Further, the hand is reduced to two fingers, bound together, and the thumb, which every one has seen in the plucked fowl. The thumb, with its feathers, is called the false wing. The feathers borne on the hand are called primaries, and those supported by the forearm are the secondaries. In some cases a few of the inner feathers of the forearm are called tertiaries. The wing is concave on the inside, making it fit the body closely when the wing is folded.

The Flying Muscles. — To use such a wing effectively as an air paddle, it is evident that there must be very strong muscles. These we find in the breast. The bulk of the breast is made up of two powerful muscles, which cover nearly the whole of the ventral surface of the body. To support these large muscles, and supply a basis for their attachment so they can work, it is equally clear that a considerable extent of bone is also a necessity; hence the large breastbone. Not only is the breastbone very large, but along its middle line is a high ridge, the keel. Lying between the body of the breastbone and the keel, and attached to both, there is on each side the large pectoral muscle, the two together constituting about one fifth of the entire weight of the body. At the anterior end, each pectoral muscle narrows into a tendon, which is attached (inserted) to the bone of the upper arm (humerus). By the shortening of this muscle the wing is pulled downward. Two points must now be kept in mind: (1) the wing is concave beneath, which enables it to "catch" the air; (2) the wider side of the vane of each quill is on the under

side, so when the wing is struck against the air, the resistance presses the vanes together in one continuous layer, through which the air cannot pass. The result is that a strong "push" is made against the air, and by reaction the bird is propelled upward or forward according to the direction of the wing stroke. In seeking the muscle that raises the wing, one would naturally look on the dorsal surface in the region of the shoulder; but, oddly enough, the muscles that raise the wings are also on the breast. Every one has noticed in the well-cooked breast of a bird that the meat of the breast separates into two parts, the outer part being large and flat, the pectoral muscle just described. Inside of this, lying in the angle between the body of the breastbone and the keel, is a slender muscle, somewhat triangular in cross section. This is the subclavian muscle. At its anterior end it narrows into a tendon, which passes up through a hole left between the bones that make the shoulder; the tendon then turns and is attached to the upper (dorsal) surface of the arm bone (humerus). When the subclavian muscle shortens, this tendon acts as a pulley, and elevates the wing. In raising the wing it is desirable that there should be as little resistance as possible. This condition is secured (1) by the convex outer surface of the wing; (2) by the fact that pressure on the outside of the wing separates the quills and allows the air to pass through with very little resistance.

The Legs and Feet. — The pigeon is a model flier. It uses the feet but little, hence the legs and feet are small and weak. Heavy legs and feet would be to the pigeon a useless burden. The hind limb consists of three parts, thigh, leg, and foot. The true heel is some distance from the toes, where we cut off the foot in dressing a bird. The part between the toes and the heel, usually covered with

scales, is the tarsus. The pigeon has four toes, one extending backward and having two joints. Of the three front toes, the inner has three joints, the middle four, and the outer five. Each toe ends in a claw.

It should be noted that the hip joints are not only far apart, but are very high on the body, being near the dorsal surface. This enables the body of the bird to swing between its two points of support, somewhat like an ice-pitcher on its two pivots. Since the bird is obliged to put its head to the ground so frequently, the convenience of this arrangement is apparent. When we stoop we realize that we are awkwardly built for such a position. It would at first seem that the bird's center of gravity is too far forward, but the length of the toes must be taken into account.

Perching. — It is to be noticed that when a bird's leg is drawn up close to its body, the toes are clenched at the same time. This is due to the action of a tendon that passes over the joints of the leg in such a way that when the limb is bent the tendon is put on a strain and thus the toes are flexed. So when the bird settles on its perch the toes grasp the perch without active muscular effort; this helps answer the question, "How does a bird stay securely on its perch when asleep?" There are also muscles by which the bird can voluntarily clutch without depending on this purely mechanical arrangement.

The Pigeon's Shoulder Braces. — With such strong pulling as the breast muscles give the wing, it will be seen that the shoulder needs to be firmly braced, especially against the strong pull of the pectoral in making the down stroke of the wing. In the first place, the shoulder is braced like our own by the collar bones, or clavicles, the two collar bones uniting near their attachment to the anterior end of the keel, together making the "wishbone." In addition

to this brace there is an additional bone alongside of each half of the wishbone, the coracoid bone, much stronger than the collar bone itself. On the back the shoulder is braced by the strong, curved shoulder blade.

To strengthen the body for the work of flying, the vertebræ of the trunk are consolidated, the only parts of the spinal column that are flexible being the neck and the tail.

The Head and Neck. — In many birds the beak is the only organ capable of being used for grasping, hence the long, flexible neck, which makes up for the above-mentioned stiffness of the trunk. The bird must be able to reach the ground, hence the length of the neck is proportioned to that of the legs; the head must also be able to reach any part of the body. Some birds have as many as twenty-four cervical vertebræ. In many birds the head must be darted forward quickly to secure prey or in defense. The horny beak is strong, yet light, and serves as a hand in picking up small objects. Because of the quick motion of a bird's head, as it picks objects out of the dirt, soft lips would be too delicate. A head that requires such quick handling needs to be light; and in keeping with this requirement there is an entire absence of teeth in all existing birds, though in a few cases rudiments of teeth are found in the embryo. In the plucked bird it is found that the neck is more slender than would appear from the outside, the feathers filling the angle between the neck and the body, and making on the exterior a gradual transition, where in the bare bird there is an abrupt change.

The Pigeon's Food and Digestive System. — Pigeons feed chiefly on grains and other seeds. These are swallowed whole, and pass into the crop, an enlargement of the gullet situated in front of the breast. Here seeds are moistened and well soaked before they go farther. The crop serves

as a storing sac during the hasty gathering of food. Inside of the body cavity is the stomach, which consists of two very distinct parts; the first part is the glandular stomach, or proventriculus, and the second is known as the gizzard. The gizzard is very strong, having thick muscular walls. In it the seeds, only partially softened, are to be ground. To aid this process small pebbles are swallowed. It is clear, therefore, that its inner wall needs to be tough;

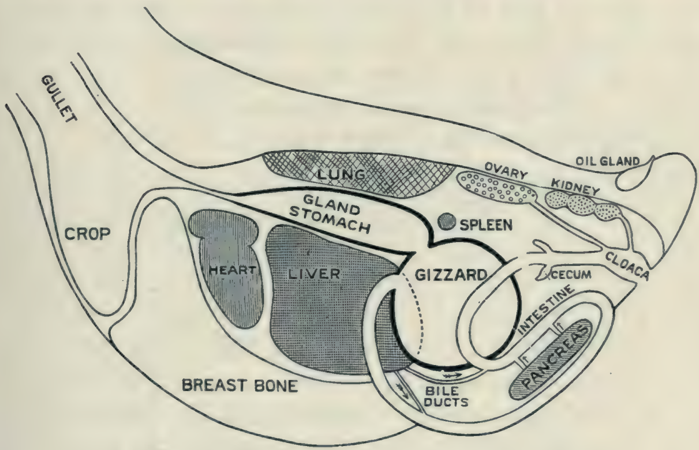


FIG. 129. INTERNAL ANATOMY OF A PIGEON.

it will not do to have the soft glands here, hence they are placed out of the way, a little higher up the digestive tube where the secretion can trickle down upon the food in the grinding stomach. The intestine arises from the gizzard; first there is a long loop, the duodenum, in which lies the pancreas. Its secretion is poured into the duodenum. The liver is adjacent and the bile duct also empties into the duodenum. The transition from the small intestine to the large intestine is marked by two small, blind side branches,

the ceca. The terminal portion of the digestive tube is widened, and is called the cloaca. It receives three sets of products, (1) the residue of digestion, (2) the eggs, and (3) the excretion of the kidneys.

The Circulatory System of the Pigeon. — The circulation of blood is very rapid in birds because of their great activity. The heart is proportionally large; it is completely divided into two halves, so that the blood moves through one half of the heart from the lungs to the body, and through the other half from the body to the lungs, being pumped twice in the circuit instead of once as in fishes. An important point to note is that the aorta turns to the right instead of to the left as in our bodies.

How the Pigeon Breathes. — Respiration is exceedingly active in a bird. Imagine yourself taking such violent exercise as that required for a bird to fly through the air at the rate of a mile a minute. Would you not be "out of breath"? The bird's lungs are of fair size; in addition there are air sacs in all parts of the body, communicating with the lungs, the bronchial tubes continuing on through the lungs into these sacs. The lungs do not lie free in the body cavity as in our bodies, but are attached to the dorsal wall, fitting closely between the ribs. The air sacs are also in communication with the hollows of the bones, which adds to the buoyancy. The temperature of birds is higher than that of any other animals, being about 110° F.

The movements of respiration in birds is peculiar, in that expiration is accomplished by active muscular effort, and inspiration by elastic reaction, — just the opposite of the processes of our bodies.

The Excretory System of the Pigeon. — The lungs serve as organs of excretion, throwing off carbon dioxid. The

kidneys are paired organs, lying embedded in the hollow of the pelvis, each kidney being in three sections.

The Oil Gland. — On the rump, at the base of the tail, is the conical oil gland. It is concealed by feathers, but when the bird wishes to oil the feathers, oil is taken from the gland by the beak and spread over them. The oil glands are the only skin glands possessed by the bird, there being no glands distributed over the skin as in many other animals.

Nervous System of the Pigeon. — The brain is relatively large. It is also wide in proportion to its length as compared with the brains of reptiles and amphibians. The anterior part of the brain consists of the two cerebral hemispheres (see Fig. 167). Back of these, in the middle line, is the rather large cerebellum, marked by transverse grooves. On the sides of the cerebellum are the two optic lobes. The whole nervous system is relatively large, the brain and spinal cord in some of the smaller birds constituting a greater proportion of the weight than in any other animals.

The Senses of the Pigeon. — Sight is the most highly developed of the bird's senses. The eye is very large in proportion to the size of the head. The outer coat (sclerotic) of the eye is strengthened by stiff sclerotic plates. The sense of sight is keen, enabling the bird to discover food and to escape enemies.

The sense of hearing is acute, the inner ear being well developed. There is no outer ear, but the depression leading to the tympanum is easily to be found back of the eye, though usually more or less concealed by feathers. The sense of touch is general over the body. Taste is apparently not very acute. While it is pretty generally believed that birds, especially carrion eaters, have a keen sense of

smell, yet experiment seems to show that this is not so acute as supposed.

The Pigeon's Voice. — The cooing of the pigeon is produced by air vibrations made in the windpipe, but not, as in most animals with a true voice, in a larynx at the upper part of the windpipe. In birds the organ of the voice is at the lower end of the windpipe, where it forks to form the two bronchi; and it is called a syrinx instead of a larynx. The bird uses the voice to utter cries of warning, to call the young, and to attract attention in the mating season. It is worthy of notice that the sweetest singers are not to be found among the highly colored birds, but among those of more subdued tints.

Origin of the Domesticated Pigeon. — All other varieties of domesticated pigeons appear to have descended from the rock pigeon of the old world. By carefully selecting pigeons having certain peculiarities, and breeding from these to the exclusion of other forms, in time we have produced a large number of varieties of pigeons, known as carriers, pouters, fantails, etc. This production of varieties by interfering with the natural selection of mates is known as *artificial selection.*

A Bird's Egg. — Birds' eggs are proportionately large. This might naturally be expected, since there is deposited within the egg sufficient nourishment to form the chick in resemblance to the adult. The eggs are formed in the ovary, and it is interesting to find that but one ovary (the left) is developed, though the right ovary is represented by a rudiment. The eggs as produced by the ovary consist simply of the yolk. On one side of the yolk is the germ spot. As the yolk, which is the real egg, passes along the oviduct, it has added to it first an enveloping mass of transparent substance which is termed the "white of the

egg," or albumen. The word "albumen" (from *album*, white) now stands for the class of substances having the same essential composition as the clear part of the egg. After the albumen is added to the yolk, the oviduct secretes a limy shell which completes the egg. The eggs pass from the oviduct through the cloaca on their way out.

Incubation. — Most birds incubate the eggs. They are sometimes laid on the bare ground, but generally in a more or less carefully prepared nest. These nests vary from a simple platform of sticks to the elaborate hanging nest of the oriole, woven of grass and soft fibers, or the still more ingenious nest of the tailor bird. It is to be noted that the nest is "simply a cradle and not a home."

The germ spot always turns uppermost, so that the developing embryo gets the heat from the body of the incubating bird. During incubation there is an increase in the amount of blood circulating in the area in contact with the eggs, a provision for affording heat to them.

The Colors of Birds. — The colors of feathers are due to two factors, first to certain coloring matters, or pigments, and second to the structure of the feather, most of the luster and iridescence being due to the latter. As a class birds are highly ornamented. The males are usually more highly ornamented than the females. Perhaps this is because the females are safer, during incubation, with dull colors. But in many families the sexes are colored alike. The young generally resemble the adult female.

Molting. — Birds shed their feathers and renew them at least once a year. If the molting takes place but once a year, it is usually in the fall, but some birds also renew their plumage in the spring. In rare cases there is a third molt. Most birds shed their wing quills in pairs, successively, so that they are at no time deprived of the use of

the wings; but the ducks shed their wing quills all at once and for a time are unable to fly. Some birds shed the claws, and the puffin sheds the outer covering of the beak.

Migration of Birds. — Comparatively few of the birds that we see during the year reside with us permanently. If one makes a list of the birds that remain through the winter, he misses many of his summer acquaintances. The crow, jay, nuthatch, chickadee, some of the woodpeckers, several sparrows, the hawks and owls, and a few others are left, when the rest have flown southward. Why do they go? The common answer is, "Because they cannot endure the cold." But if one examines the feathers he finds little difference between the robin and the jay, or the bluebird and the sparrow. It is chiefly a question of food. The robin and the bluebird live mostly on insects and worms. As winter approaches these birds can no longer find this sort of food in northern latitudes, and they seek a warmer climate, not so much because they cannot stand the cold as because insects and worms cannot stand the cold. Woodpeckers are insectivorous, yet remain; but they can get the larvæ from the trees about as well during the winter as in the summer. The large majority of the birds that remain with us during the winter are either seed-eating birds, like the grouse and sparrows, or carnivorous, as the hawks and owls. Some are omnivorous, like the crows and jays. Some birds, such as the swallows, are very regular in the times of their migrations. Others are irregular, and some birds migrate or not, according to varying conditions. We must keep in mind the bird's marvelous power of flight; in a short time he can cover a very great distance.

Parasitic Birds. — Perhaps the most common example of the parasitic habit is seen in the common cowbird.

It lays its eggs in the nests of smaller birds. The eggs, being larger than those of the owner of the nest, receive the most heat, and are likely to hatch first and prevent the development of the rightful heirs; thus the usurper succeeds. Our cuckoo builds its own nest and should not be confused with the English cuckoo, whose bad reputation is sometimes transferred to his American namesake.

CHAPTER XV.

BRANCH CHORDATA.

CLASSIFICATION OF AVES.

Existing birds are divided into two great groups. All flying birds have the keeled breastbone, and from this fact of structure are placed together in the division Carinatæ. meaning "keeled." The ostrich has no keel on the breastbone, hence is placed in the division Ratitæ, from a word meaning "raftlike," referring to the shape of its breastbone.

DIVISION I.—RATITÆ.

The best-known representative of this division is the African ostrich. It cannot fly, the wings being small; but it is a swift runner, equaling a horse in speed. The breastbone is not only without a keel, but is relatively very small, as might be expected since there are no large flying muscles. The feathers on the wings and tail have no hooklets on the barbules; the result is a plume instead of a firm vane as in the flying birds. These plumes have been valued as ornaments from the earliest time, and now the rearing of ostriches for the plumes is an important industry in South Africa and southern California.

The ostrich is also noteworthy from its size, being the largest of existing birds, standing from six to eight feet high. It has but two toes on each foot. In the same division are also the South American ostrich, the emu of Australia, the cassowary of Australia and the East Indies. The kiwi of New Zealand has bristlelike feathers,

so that it appears to be covered with hair, and the nostrils open at the tip of the long beak. The Ratitæ are "overgrown degenerate birds that were once on the right road for becoming flying fowl, but through greediness and

FIG. 130. SOUTH AMERICAN OSTRICH.
From Kingsley's *Zoölogy*.

idleness never reached the 'goal,' went back, indeed, and lost their sternal keel; and almost lost their unexercised wings" (Parker).

DIVISION II.—CARINATÆ.

This division includes all flying birds. All of the birds in this part of the world are carinate. The breastbone

is large and keeled to support the flying muscles. The barbules have hooklets which unite the barbs, forming a firm vane. The Carinatæ are divided into a number of orders.

The Diving Birds. — The diving birds have webbed (or lobed) feet and are expert in swimming and diving. The wings are usually small or rudimentary. In many the tail is rudimentary. Our local examples are the grebes and loons, though these are little seen except by the field naturalist, hunter, or fisher. Their legs are set far back in adaptation to their main use, the result being that they must stand upright and can hardly walk. The plumage is thick and well oiled, to fit them for diving. Water does not penetrate between the feathers, so the skin is not wet. The grebes have lobed toes and are about the size of our smallest ducks. They dive like a flash when alarmed, but it is not true that they can dive between the flash of a gun and the time that the shot can reach them. The grebe is commonly called "hell-diver." The loon is our largest diver. Its peculiar cry, sometimes resembling a hysterical laugh, has given rise to the expression, "crazy as a loon." The loon does not try to escape pursuers by flight, but dives and swims long distances under water, so that it is seldom shot.

FIG. 131. PIED-BILLED GREBE OR HELL-DIVER.
From Eckstorm's *The Bird Book.*

The auks and puffins are found in vast numbers on the coast of Labrador and northward, some having great powers of flight.

FIG. 132. THE LOON.
From Eckstorm's *The Bird Book.*

The penguins are correspondingly characteristic of Patagonia and the Antarctic regions. Their wings are small and paddlelike, and are covered with scale-like feathers.

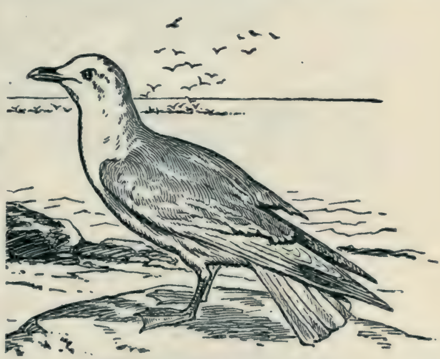


FIG. 133. HERRING GULL.
From Eckstorm's *The Bird Book.*

The Long-winged Swimmers. — This group includes the gulls and terns. They are web-footed and have long wings and tail, with remarkable power of flight. They occasionally rest upon the water, coming on shore only to lay their eggs. They are mostly sea birds. though some frequent inland lakes and rivers, and any one

who has taken a trip by steamer has watched them and wondered at their tireless flight. The gulls have hooked beaks, while those of terns are pointed and nearly straight; in both the bills are often bright-colored. They feed chiefly on fishes, but some are scavengers, following ships.

The Tube-nosed Swimmers. — To this order belong the petrels, which resemble the gulls except in having the nos-

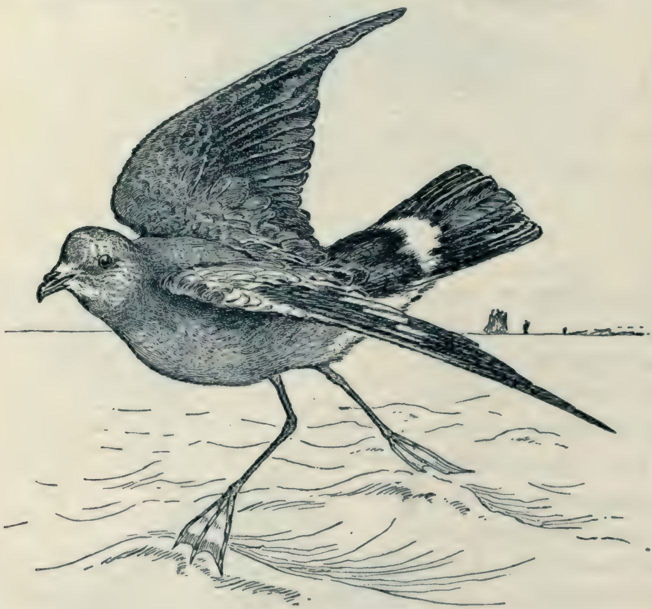


FIG. 134. PETREL.
From Eckstorm's *The Bird Book*.

trils open as two parallel tubes on the top of the beak. Perhaps best known, or at least most read about, are the stormy petrels, or "Mother Carey's chickens." Closely related also is the albatross of the southern hemisphere, which has a spread of ten feet.

The Totipalmate Birds. — As the name indicates, the birds of this order have *full-webbed* feet; that is, there are not merely two webs between the three front toes, as in ducks and most web-footed birds, but there are three full webs, the hind toe being connected by a web with the

FIG. 135. THE CORMORANT.
From Eckstorm's *The Bird Book.*

inner front toe. Our most familiar examples are the cormorants, but they are shy birds, found in the lakes and larger streams. They are voracious fish eaters. Nearly every one has seen the pelican, as it is frequent in zoölogical gardens and menageries. The cormorant has a rudiment of the throat pouch so conspicuous in the pelican.

In the East Indies the pelican is tamed and used in fishing, as is the cormorant in China.

The Ducks and Geese. — These birds have webbed feet, with heavy, oily plumage. The body is flattened, and all are fine swimmers. The bill is frequently broad, with a sort of saw edge. The tongue is fleshy. In the geese and fish ducks the bill is narrow. The swans belong to this

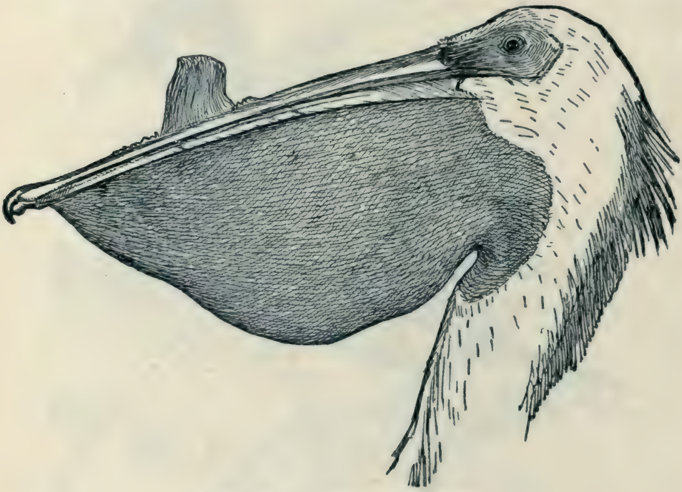


FIG. 136. HEAD OF PELICAN.
From Eckstorm's *The Bird Book.*

group. Our domesticated duck closely resembles the wild mallard, from which it is descended. The downy feathers are much used for pillows, etc. Some ducks dive well, and live largely on fish, which diet gives their flesh a rank, fishy flavor; but the fine flavor of the canvasback is thought to be due to the wild celery on which it feeds. The wood duck, and a few others, are exceptional in nesting in trees, though, of course, near water. Ducks and

geese attract attention by their migration in large flocks, especially in the spring. But their former vast numbers have been reduced, mainly by those who shoot them for market.

All the above-described orders are often classed together as the "swimming birds."

Herons and Storks. — These are slender-bodied, long-legged, and long-necked, with long, sharp bills, living about the water and feeding chiefly on fishes, etc. They are fitted for wading, not only by their long legs, but also

FIG. 137. WOOD DUCK.
From Kingsley's *Zoölogy.*

by the fact that the feathers extend only part way down the tibia. The long neck is ordinarily kept bent in an S-shape, and can be quickly darted out to seize food. Among the herons are the big blue heron, seen along the rivers and creeks, the white egret, the bittern or stake driver, the night heron, and the little green heron. In the breeding season the head bears long plumes that are much sought as ornaments.

The Cranes and Rails.—This group also consists of marsh birds, usually with long legs and necks. The cranes are large, the white or whooping crane having a very long windpipe coiled in a hollow in the breastbone. The rails are smaller birds, not larger than a hen. These are seldom seen except in reedy swamps. The coot, or mud hen, is common in marshes and reedy lakes; it has a bill like a hen. It is an excellent swimmer, but has lobed instead of webbed feet. The flesh is rather rank; but as ducks are becoming more scarce, the coot is not unfrequently substituted.

The Shore Birds.—This order includes the snipes, plovers, etc. Like the two preceding orders, its members usually have long bills, neck, and legs. The three orders are often spoken of together as the "waders." The long, slender bill is often soft and sensitive at the tip, to fit it for probing in the mud for worms. Several of the snipes are highly esteemed by epicures, especially the woodcock and "jacksnipe."

The plovers are found rather more on dry land; they have no hind toe. The golden plover is often seen in large flocks during its migration, and nearly every one knows the killdeer by the cry from which it gets its name.

The Gallinaceous Birds.—The Gallinæ, or fowls, have robust bodies, well-developed legs, strong, blunt bills and claws. The hind toe is elevated, that is, is attached higher than the other toes. They are poor fliers, having relatively short wings. They are essentially ground birds, none making their nests in trees. They feed chiefly on seeds and grains, the crop and gizzard being well developed. On account of their plump bodies and the excellent quality of their flesh, they are valued as food. Other animals than man prey upon them; and as they live on the ground, where prowling enemies can gain easy access to them, we should expect to find them colored for protection; and, in

fact, they wear grays, browns, and blended colors resembling grass, weeds, and brush. The turkey is a native American, though bearing a foreign name. Except the turkey, all our native Gallinæ belong to the grouse family.

The quail is widely known as "bob-white." It is very cunning, and holds its own fairly well when properly protected by law.

The partridge, or ruffed grouse, lives in the woods. On account of its wildness, it persists where native forest still stands. It makes a loud noise by beating its wings rapidly (drumming).

The prairie hens once abounded on the prairies of the Central states, but are fast disappearing. Even though protected by law eleven months of the year, they seem doomed to extermination. They lack the cunning of the quail, and their size is a disadvantage. The cock has a bare colored spot on each side of the neck. This is inflated while making his booming noise in the mating season, and gives him the appearance of having an orange on each side of the neck.

The sage grouse (sage hen) is found on the Western plains among the sage brush. Sage hens are very good to eat early in the season, but later are often tainted by eating sage leaves, which makes the flesh bitter. The sage hen is peculiar in lacking a gizzard.

One of the most interesting of the grouse is the ptarmigan. It is a rock grouse. The American species is found in the Rocky Mountains, living on the rocks above timber line. The legs and feet are fully feathered down to the base of the claws. It has in summer a mixed gray and brown color that makes it inconspicuous on lichen-covered rocks. In the winter it turns pure white, and in fall and spring is partly gray and partly white in transition.

Our common fowl are descendants of the jungle fowl of India, which our ancestors took from a wild state and domesticated. The guinea fowl, peafowl, and turkey are other domesticated gallinaceous birds, these domesticated forms all belonging to the pheasant family. It is remarkable that the breast muscles should retain their large size when they are so little used. Of late, pheasants from the old world have been introduced in various parts of this country. The Gallinæ are undoubtedly the most valuable to man of any order of birds.

FIG. 138. THE RUFFED GROUSE.
From Eckstorm's *The Bird Book*.

The Doves. — The doves are characterized by a soft, swollen membrane, or cere, overhanging the nostrils at the base of the bill. They are strong fliers, with heavy flying muscles and small, weak legs. This is a small order. The wild pigeon, formerly existing in countless numbers, is now well-nigh extinct. The turtledove, or mourning dove, however, remains abundant in the Central and Western states, finding abundant feed in the grain fields.

The Birds of Prey. — Birds of prey usually have stout, hooked beaks and sharp, curved claws, fitting them for clutching and tearing their prey. They do not have a gizzard, not needing such a stomach for digesting flesh. The colors are usually dull, the sexes generally being colored alike. The females are usually larger than the males. There are three principal forms of Raptores, illustrated by the hawk, the owl, and the vulture.

The hawks are the best examples of the order. They are keen-eyed, strong of wing and leg. There is much ungrounded prejudice against them, for, with the exception of Cooper's hawk and the sharp-shinned hawk, most of them do more good than harm, killing large numbers of mice, especially field mice. The eagles belong to the same family (Falconidæ) as the hawks. The so-called "bald-headed eagle" is not bald; but in old age the feathers of the head and neck are white, making the name "white-headed eagle" appropriate. The adult is smaller than the younger eagle. This bird hardly deserves to be chosen as the emblem of this country, as he is a notorious robber. Often he perches, waiting and watching, till an osprey, or fishhawk, has captured a fish; then he swoops down upon him and snatches away the prize. The golden eagle is a distinct species, characterized by being full-feathered down to the toes.

The owls have both eyes facing forward. The eyes are large, and have very dilatable pupils, thus enabling them to see well at night. Owls have a soft plumage and an almost noiseless flight. They depend more on stealth than on swiftness for securing their prey. They do much good by

FIG. 139. THE MARSH HAWK.
From Grinnell's *Our Feathered Friends.*

destroying rats and mice. They swallow birds and mice nearly whole; later the bones, hair, and any other indigestible portions are ejected from the mouth. Many owls have tufts of feathers called "ears," "ear tufts," or "horns," but these probably are merely ornamental. The great horned owl is well known by its hoot, "hoo-hoo, hoo-hoo,

hoo-hoo, hoo-hoo," the last note prolonged with a circumflex accent.

The common little screech owl shows an interesting variation in color. Two colors are found, a gray and a reddish. It was at first thought they belonged to different species, but these two colors have been found in young of the same brood. The difference seems to have no relation to age,

FIG. 140. TURKEY BUZZARD.
From Grinnell's *Our Feathered Friends*.

sex, or geographical distribution, nor do there seem to be intermediate individuals. There are evidently two styles of dress with the screech owls. This occurrence of two styles of plumage is known as "color dimorphism."

The vultures are degenerate Raptores, usually carrion eaters. The head and neck are usually bare, and the bill and claws weaker than in the above-described forms. Many

of them are large, and soar gracefully hour after hour high in the sky; but when they descend to earth they show their disgusting nature. Yet they are useful as scavengers, and are wisely protected by law, especially in the South. Our only example in the Northern states is the turkey buzzard, which has a spread of six feet. In the South is found also the carrion crow. This must not be confused with our common crow, which, though carnivorous, is classed with

FIG. 141. CAROLINA PARRAKEET.
From Kingsley's *Zoölogy*.

the Passeres, or perching birds. The condor of the Andes is a vulture; though feeding chiefly on carrion, it sometimes kills lambs and other small animals. Exaggerated accounts of its size and ferocity are common; measurements do not show that it exceeds a spread of eleven or twelve feet.

The Parrots. — Parrots have a soft, fleshy, mobile tongue, and can learn to talk. They have the toes in pairs, and can climb well. The bill is large and so strong they can

crack hard nuts. Most of the group are tropical birds, as the macaws and cockatoos, and have gorgeous colors. The only example of the order found in the United States is the parrakeet of Florida.

The Cuckoos. — The cuckoos have the toes in pairs, the outer front toe having been turned backward. In the same group are placed the kingfishers, though this order is confessedly a "mixed lot" that were thrown out of the old group of "climbing birds."

FIG. 142. DOWNY WOODPECKER.
From Grinnell's *Our Feathered Friends*.

The Woodpeckers. — The woodpeckers are typical climbers, the feet being zygodactyl, that is, with two toes turned forward and two backward. In climbing, the stiff tail feathers assist by bracing against the tree below. The bill is straight, hard, and chisel-like, the strong neck muscles using it to drill a hole through bark and wood after insect larvæ. When the larva is reached, it is secured by the slender tongue, hard and barbed at the tip, which is darted out and withdrawn with force and precision. The mechanism for projecting the tongue can hardly be understood without actual examination. There

are two slender cartilaginous rods which pass backward from the tongue under the angle of each jaw, up and forward on top of the head, in some cases even nearly to the tip of the bill. The cartilaginous rods furnish stiffness, so that a muscular sheath can be effective. Woodpeckers do good by destroying borers. Only one kind, the true sap sucker, or yellow-bellied woodpecker, uses the wood or sap, thus being somewhat injurious.

FIG. 143. NIGHTHAWK.
From Packard's *Zoölogy*.

The Swifts and Humming Birds. — The birds of this order have long, pointed wings, the primaries being especially elongated. The feet are small and weak. The swifts are well known to every one under the name "chimney swallows," but they are not closely related to the true swallows. The humming birds are the smallest of birds and among the most beautifully colored. The tongue is long and extensible, and is used in securing insects from tubular flowers, over which they are often seen hovering.

The nighthawk and whip-poor-will are in this order. They are fitted for catching insects on the wing by the very wide mouth, the gape extended far along each cheek, while the bill itself is small and weak. These birds fly at night or at dusk. When they light on a branch, they always sit lengthwise, never crosswise, and, as they lie quite flat and are of a grayish tint, they are very hard to see.

The Perching Birds. — This is the largest order of birds. Its members have the toes fitted for perching, with three toes turned forward and one backward, all on the same level; most of them are "tree" birds, and are small or medium-sized. There are usually twelve tail feathers and nine or ten primaries.

The flycatchers include the kingbird and pewee. The crows and jays are known by their harsh voices, omnivorous appetites, and thievish habits. They do harm by eating the eggs and young of many birds. The blackbirds and orioles form a well-known family, including the parasitic cowbird, the bobolink, and meadow lark. The sparrows, or finches, are the largest family of perchers. They have stout, cone-shaped beaks, with the "corners of the mouth drawn down." Most of the sparrows are of rather dull colors, streaked grays, drabs, and browns prevailing, as in the tree sparrow, chipping sparrow, and snowbird. Still, many of these have patches of yellow, white, or chestnut feathers. Some are conspicuously colored, as the purple finch, wild canary, or thistle bird, the indigo bird, and the cardinal and rose-breasted grosbeaks.

FIG. 144. KINGBIRD.
From Packard's *Zoölogy*.

The English sparrow was introduced into the United States about 1850, with the hope that it might check the ravages of the "cankerworm" and other tree-infesting caterpillars. The importation was a failure. It is doubtful if these sparrows do much good in the way of eating

obnoxious insects. Certain it is that the English sparrow drives away many birds that were very useful in destroying such insects. The English sparrow is a bold, pugnacious bird; he makes himself at home, but drives from home many of our fine birds, such as the bluebird, pewee, and wren. This sparrow, like most sparrows, is mainly a seed eater, and does considerable damage in this way. A further charge against him is his dirty habits.

The swallows are another interesting family, comprising the "swallow-tailed" barn swallow, the eave swallow, the

FIG. 145. BUTCHER BIRD; SHRIKE.
From Miller's *My Saturday Bird Class.*

bank swallow, which makes its nest in long, horizontal holes in steep banks, and the half-domesticated martin.

The shrikes are hawklike in appearance and in habits, having a hooked beak and sharp claws. They catch mice, frogs, small birds, snakes, grasshoppers, etc., and impale them on the thorns of hedges and other trees. From these habits they are also called mouse hawks and butcher birds. A large family of small birds called warblers live in tree tops, and are not well known except to those who take special pains to study them. The sprightly wrens are placed in the same family with the mocking bird, catbird, and brown thrush. These last three are superb singers. Another fine songster is the wood thrush; though placed in

a different family, it resembles the brown thrush in having a tawny back and a light-colored breast, with brown spots, the tail being shorter than that of the brown thrush. The mocking bird is more southern, occurring mainly south of the latitude of the mouth of the Ohio River. The nuthatch and chickadee remain through the winter, as they feed on insects found beneath the bark of trees. The nuthatch has the climbing habits of a woodpecker, but its

FIG. 146. BLUE JAY.
From Grinnell's *Our Feathered Friends.*

toes are arranged as in perchers. It is not excelled as a climber, going sideways or head downward, as well as upward. Among the highest in development of all birds is the bluebird, which, unfortunately, is growing rare in the Central states, especially about towns, where it was formerly common. Perhaps no bird ranks higher in its general organization than that bird so dear to every American child, the robin.

Fossil Birds. — In rocks in various parts of the world have been found remains of various extinct birds. Some of them were larger than any existing, — ten feet in height. One egg has been found, the capacity of which equaled one hundred and fifty hen's eggs. But more interesting than the great size is the peculiar structure of some of these ancient birds. Many of them possessed teeth, and some

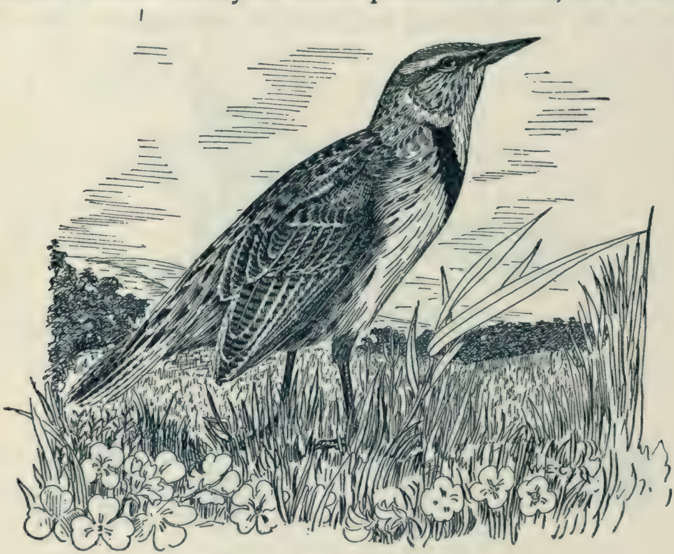


FIG. 147. MEADOW LARK.
From Grinnell's *Our Feathered Friends.*

of these teeth were set in sockets, a feature we did not find till we reached the highest of the reptiles. One fossil, found in Bavaria, had not only teeth, but also a long tail, consisting of many vertebræ, with a pair of feathers extending out on each side from each joint.

Relations of Birds and Reptiles. — Not only do fossil remains show points of structure in common between these

two groups, but if we compare the structure of modern birds and reptiles, we find likenesses that are not apparent on superficial examination. Feathers and scales are of the same origin; the bird has both. The feathers of the wing of the penguin are scalelike. The head joins the first vertebra in the same way in both by a single occipital condyle,

FIG. 148. BALTIMORE ORIOLE AND NEST.
From Grinnell's *Our Feathered Friends*.

that is, the head pivots on a single rounded process, instead of on two, as in our bodies. The tongue of a snake is supported in the same way as in a bird, and both are more or less protrusible. Both lay large eggs, and there are points of development in common that cannot be considered here. All these facts, here scarcely hinted at, go to show that birds have descended (or ascended) from

reptiles. Hence many authors include birds and reptiles in the one group, Sauropsida, just as the fishes and amphibians are placed together in the group Ichthyopsida.

Game Birds. — The principal game birds are the various kinds of grouse (the quail, prairie hen, partridge, sage hen), the ducks and geese, and various wading birds, including snipe, rails, plovers, etc. But the food value of these is not great. All sportsmen who wish a continuation of these game birds should agree in enacting such laws as shall protect them so their numbers may not be greatly reduced. The general sentiment is that they ought not to be killed for market purposes, nor during the breeding season.

Value of Birds. — The value and importance of game birds sinks into insignificance in comparison with the smaller birds. When we stop to consider the ravages of insects, those that infest the fields and orchards, forests and groves, the many larvæ at the roots and on the foliage, the caterpillars, cankerworms, etc.; and on the other hand the multitude of birds — mostly of small size — the robin and bluebird, the cuckoos and warblers, flitting about in the tree tops all day long in search of these noxious insects, — when all these facts are weighed, we may well raise the question whether, if all bird life on the globe were destroyed, the earth would long continue habitable by man. As it is, occasional plagues of insects strip large areas of plants and bring on local famine. These birds should be fully protected by law. Till lately the number of many of these birds has rapidly decreased, owing to their being killed for their plumage, to the collection of eggs, and to wanton and aimless destruction. Besides game birds none should be killed, except for scientific purposes, unless they are themselves noxious, as crows and jays, the English sparrow, a few hawks, and possibly a few others.

General Characteristics of Birds. — The possession of feathers is sufficient to distinguish birds from all other animals. The consolidation of the thoracic vertebræ and the pelvis is peculiar. The bones of the cranium are united in one, the sutures disappearing early. The ribs are provided with flat braces extending to adjoining ribs. The breastbone is large, and usually has a well-developed keel. The two collar bones (clavicles) unite to form a wishbone. Air sacs are connected with the lungs. The temperature of the blood is high. The red corpuscles are elliptical and have nuclei. The brain is relatively large, the eye especially being large in proportion to the size of the head. The organ of the voice is at the lower end of the windpipe, instead of at the upper.

CLASSIFICATION OF BIRDS.

		ORDERS.	EXAMPLES.
Class Aves	Division Ratitæ	1. Struthiones	Ostrich
	Division Carinatæ	2. Pygopodes	Loon
		3. Longipennes	Gull
		4. Turbinares	Petrel
		5. Steganopodes	Pelican
		6. Anseres	Duck
		7. Herodiones	Heron
		8. Paludicolæ	Crane
		9. Limicolæ	Snipe
		10. Gallinæ	Quail
		11. Columbæ	Pigeon
		12. Raptores	Hawk
		13. Psittaci	Parrot
		14. Coccyges	Cuckoo
		15. Pici	Woodpecker
		16. Macrochires	Nighthawk
		17. Passeres	Robin

CHAPTER XVI.

BRANCH CHORDATA.

CLASS MAMMALIA.

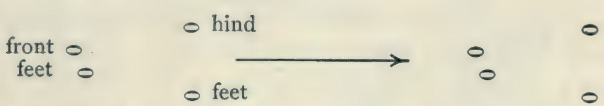
Example. — The Common Rabbit.

Habits. — The common gray rabbit is familiar to many under the name of "cottontail." This name is due to the white fur of the ventral surface of the tail. As the tail is held erect, the white part is very conspicuous when the rabbit is running away from the observer. Our rabbit — unlike the English rabbit — does not burrow, though it sometimes takes to holes to escape pursuit, and perhaps lives in them when other shelter is not convenient. In pleasant weather the rabbits stay most of the time in rather open spaces, hiding in bunches of grass. They do not make any nest at such places, but simply find, or make, an opening in a convenient tuft of grass, where they squat. Such place is called a "form." In colder weather, especially when there is snow, they find a more complete protection in brush heaps, hedges, and patches of weeds, or even in burrows. They are nocturnal, sitting quiet all day, or coming out only in the cool part of the summer mornings and evenings. But at night they come out and run about for food, and many observers think they are very social and enjoy playing together.

Covering of the Rabbit. — The rabbit has a covering of hair. The bulk of the covering, the fur, is made up of short, soft hairs. Among these, and more deeply embedded

in the skin, are a number of long, straight hairs with dark tips. They make an admirable covering during the cold of winter. The feet are also covered by hairs, and the inside of the cheek is hair-lined.

The Rabbit's Mode of Locomotion. — It should first be observed that the hind limbs are much larger and stronger than the fore limbs. The back and loins are well-muscled, all fitting the rabbit for running. When it is undisturbed, and moving about in search of food, it simply hops. But when frightened, it runs swiftly. In running, the chief propelling power is the hind limbs, which, when straightened, are efficient means in pushing the body forward. Before each leap the body is doubled, or arched. Then the body straightens by the action of the muscles of the back and the hind limbs. At the end of the long leap the rabbit alights on the front feet, but the long hind legs swing forward, one on each side, straddling the fore legs, so that the foremost tracks, in the set of tracks made at each leap, are made by the hind feet, and the two smaller tracks, which are closer together, are made by the front feet, as follows: —



Not unfrequently the rabbit sits erect, resting on the whole length of the hind feet. Ordinarily the rabbit walks or runs on the toes only. The true heel in the rabbit is off the ground in running, and is where we usually cut off the foot when dressing the rabbit.

Food of the Rabbit. — The rabbit is herbivorous, eating clover, grass, etc., with an especial liking for many garden vegetables. It is, therefore, commonly found around gar-

dens and orchards. The rabbit likes such places, not only on account of the food there found, but also because of the shelter afforded by the grass and bushes. In winter, when fresh vegetation is scarce, the rabbit eats twigs, especially the buds and bark; thus a brush heap of fresh cuttings from such trees as the apple affords the rabbit both shelter and food.

The Rabbit's Teeth. — At the front of the mouth are two pairs of chisel-shaped teeth, the incisors. These teeth are mainly composed of dentine. On their front surfaces is a layer of hard enamel. The result of this hard front edge is that in gnawing, the hinder edges of the teeth are worn away faster and the teeth are kept constantly beveled; in other words, they are self-sharpening. These teeth grow at the base of the roots as fast as they are worn away at the outer ends. If one of these teeth should be broken off, or otherwise destroyed, the opposing tooth would no longer be worn down and would grow too long, and sooner or later interfere with the process of eating and cause starvation. Many cases of this kind among rodents have been known. Back of the upper incisors is another, smaller pair of teeth, also regarded as incisors, an arrangement peculiar to the rabbits and not found in other rodents. Back of the incisors is a considerable space without any teeth, before the grinding teeth, or molars, are reached. This space undoubtedly enables the rabbit to manage the mouth better in gnawing, just as in most of our pinchers we have a widened space back of the nipping jaws. The same arrangement is found in the horse, cow, etc.

The molars are six above and five below, set in close rows, and having ridges running crosswise. The direction of these ridges must be considered in relation to the joint by which the lower jaw articulates with the skull. This

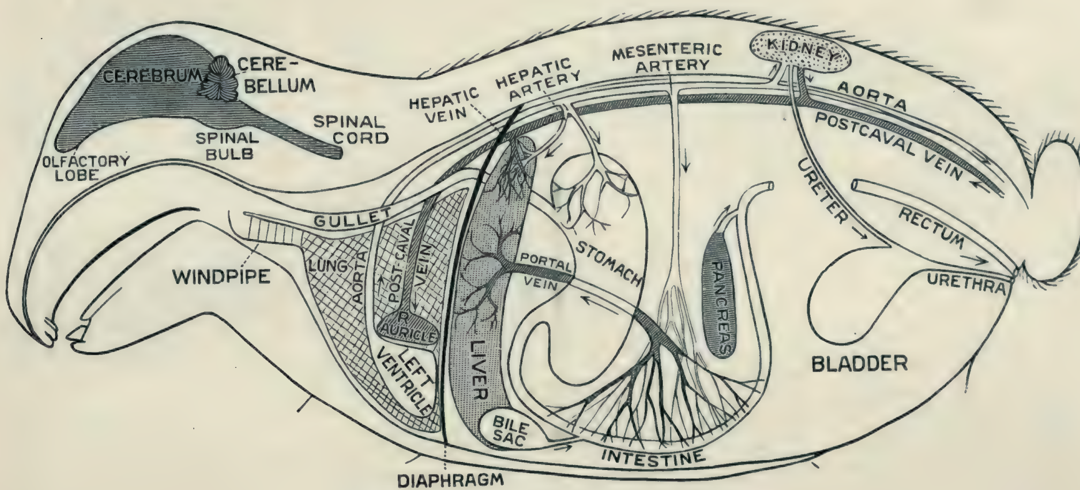


FIG. 149. INTERNAL ANATOMY OF A RABBIT.

joint is not a regular hinge joint, such as we find in a cat, which allows of little more motion than a door hinge. The rounded knob at the upper end of each jawbone fits into a groove which runs front-and-back, thus allowing the jaw to be moved forward and back. If one watches a rabbit chewing, he will see that this motion is characteristic in place of the more decidedly lateral movement seen when a cow is ruminating. The ridges of the upper and lower molars, therefore, are drawn back and forth over each other, thus effectively grinding the food.

The Process of Digestion. — There are four pairs of salivary glands on each side of the head, which pour their secretions into the mouth to aid in digestion. At the base of the tongue is the epiglottis, a cartilaginous cover which turns down over the opening into the windpipe when the food passes over it on the way to the stomach. The gullet extends through the thorax, piercing the diaphragm, and enters the large stomach, which lies back of the diaphragm, partly separated from it by the liver. On the liver is the bile sac, from which the bile is poured into the first part of the intestine, called the duodenum. The long, coiled small intestine finally joins the large intestine, and at their junction is a long, blind tube, or sac, the cecum. Near the stomach is the pale pancreas, which empties its secretion by a duct into the duodenum.

Since the rabbit eats food that is relatively poor in nourishing material, it is obliged to eat a large amount; and as vegetable food, especially with a good deal of cellulose, is difficult of digestion, we should expect to find the digestive tube both long and capacious, and this is the case. The intestine is about ten times the length of the rabbit's body. While the rabbit sits in concealment during the day, the slow process of digestion is going on.

The Circulation of Blood in the Rabbit. — The rabbit's circulation is essentially as in our bodies. The heart is completely divided into two parts, the right and left halves. The right half pumps the blood to the lungs, whence it returns to the left half of the heart to be pumped to all the other parts of the body through the main artery, called the aorta. The heart is within a pericardium, situated between the two lungs, and resting against the diaphragm, near the ventral body wall.

How the Rabbit Breathes. — The rabbit's respiration, too, is very like ours. The diaphragm is a thin sheet of muscle that arches across the body at about the posterior border of the longer ribs, separating the body cavity completely into two cavities, the anterior containing the heart and lungs, the posterior containing the stomach and intestines, with the liver, pancreas, kidneys, bladder, etc. By the shortening of its muscle fibers the diaphragm is moved backward, thus drawing in the air. The muscles which move the ribs in and out also do part of the work. The lungs are similar to ours, being light (hence called "lights") and porous, all the air vesicles being reached by minute branches of the bronchial tubes, which fork from the windpipe. The temperature of the rabbit's blood is considerably higher than our own, averaging 103° or 104° F.

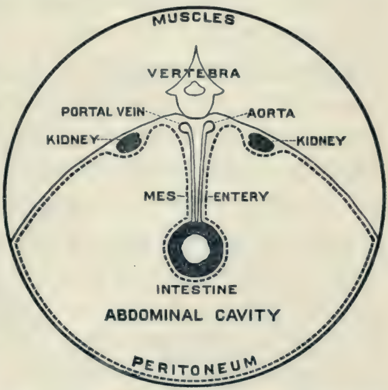


Fig. 150. Cross Section of Abdomen of Mammal.

The Excretory Organs of the Rabbit. — The lungs act as excretory organs, throwing off carbon dioxid as well as absorbing oxygen. The kidneys also are organs of excretion. The kidneys are bean-shaped bodies attached to the dorsal wall of the abdominal cavity. To each kidney runs a branch of the aorta, supplying it with blood, and from the kidney a vein returns the blood to the postcaval vein. As the blood flows through the kidney in fine tubes called capillaries, the kidney removes from it certain impurities, especially the waste matter that contains nitrogen. The excretion is conveyed backward by a tube called the ureter, and emptied into the urinary bladder, an organ not possessed by the birds or reptiles.

Enemies of the Rabbit. — Among the enemies of the rabbit are dogs, wolves, foxes, cats, both wild and domesticated, minks, weasels, hawks, owls, and perhaps many others. In addition to these larger foes, the rabbit is usually infested by parasites, such as fleas, tapeworms, etc.

How the Rabbit escapes his Enemies. — The rabbit has claws, but they are not very efficient as a means of defense. Rabbits use their teeth in fighting one another, but these avail nothing against their enemies. The rabbit is practically defenseless, and relies upon two means for protection, — the first is its color, and the second its speed of flight. The prevailing color of the rabbit is gray, varied with some blackish, and more or less tinged with yellowish brown. In the summer he appears rather more rusty or tawny. He is so like his surroundings that it takes a keen and practiced eye to detect him when he sits perfectly quiet in his form. This he usually does, relying on his color to protect him. Besides his color, his position is an aid in concealment, for he is snugly doubled up, the ears folded down closely along the back, and the white tail is out of sight. He generally

sits in the center of a tuft of grass, and frequently he appears to select a small bunch of grass, just large enough to cover him scantily, perhaps thinking that he will not be looked for in such slight cover. Sometimes a rabbit will start from his form when an enemy is at a distance, especially if much noise is made; at other times he may be approached closely, and almost touched, before he will stir. When he does start, it is usually with a dash; and he generally runs with great speed to another cover, often running through hedges and other places that will prove an obstruction to pursuers. If followed, especially by dogs, the rabbit frequently runs in a circle, and after completing the circle, suddenly jumps far to one side, thus throwing the follower off the scent. Though speedy, the rabbit is not an enduring runner. He carries too much weight. The bulky food and the large amount he eats prove a handicap. His paunch suggests that of the cow. A dog has the advantage. Being a meat eater, he has a short intestine, whereas that of the rabbit is long. The dog's food is concentrated, nutritious, and quickly digested; hence the dog is light in the abdomen, where the rabbit is heavy. Further, the heart of the dog is stronger relatively, and a strong heart is the chief factor in long-windedness. But in spite of his relative short-windedness, his running and his cunning often enable him to escape.

Injury done by the Rabbit. — Rabbits do considerable harm by gnawing the bark of young trees in orchards, and in some places it is necessary to build a protection around the trees to save them. The English rabbit, introduced into Australia, has become a plague. In spite of all the means that man has been able to devise, they multiply beyond any checks that can be applied. High rewards have been offered for any means that will exterminate

them, and bounties are continually paid for killing them; they thrive in spite of all that can be done. The introduction of contagious diseases has not been a success.

Uses of Rabbits. — In this country they are used only for food, and that to a very slight extent; but in Australia and some other parts of the world the fur is saved and used in making felt. This is an important industry, as practically all our "derby" hats are made of rabbit fur. Most of the fur goes to London to be dyed.

Development of the Rabbit. — The ovaries are small ovoid bodies attached to the dorsal wall of the abdominal cavity, posterior to the kidneys. The eggs are microscopic, and when set free from the ovary, enter the free opening of the oviducts, as in the case of the frog. The posterior end of each oviduct is developed into an organ called the uterus, for holding and nourishing the egg, which is here retained till development to the form of the parent is reached. The young are born alive, and for a time after birth they are nourished by milk from the mammary glands of the mother. From four to seven are usually in a litter, more commonly five or six. As several litters may be produced during a year, the rate of their increase is very rapid; but their fatalities are enough to keep their numbers down in this part of the world. The little "cottontails" are concealed in a fur-lined nest, which is a pocketlike hole in the ground.

The Nervous System of the Rabbit. — The brain is fairly well developed, but the rabbit has not a high intelligence; and as in the other lower orders, the surface of the brain is nearly smooth instead of convoluted, as is the case with brains of the higher animals. The principal parts of the brain are the cerebrum, with its two hemispheres tapering forward into the olfactory lobes (see Fig. 167). Back of the cerebrum is the irregular cerebellum, with a central and lateral

lobes. From the ventral surface of the brain the spinal bulb arises, and continues into the spinal column as the spinal cord. From the brain arise twelve pairs of cranial nerves, and from the spinal cord a series of paired spinal nerves which supply the body.

The Senses of the Rabbit. — Sight and hearing are especially well developed. The eyes are prominently placed on the sides of the head, so that the rabbit can see an enemy approach from any direction. The ears are long, and can be moved by muscles so as to turn in any direction to catch the sound. Rabbits may not unfrequently be seen to sit erect and prick up the ears as if suspicious of danger. When at rest in concealment, the ears are laid flat on the back. The sense of smell seems well developed. The nostrils are longitudinal slits at the end of the nose, and between them is a cleft, from which fact we borrow the term "hare-lip." This arrangement apparently gives greater mobility to the lips in feeding, and in sniffing there is considerable range of movement of the upper lip and nostrils. Taste also appears to be fairly keen, judging by the rabbit's discrimination in choice of foods. Microscopic examination of the tongue shows essentially the same taste organs and nerve supply as in our tongues. The sense of touch appears to be distributed all over the body, though probably more keen about the nose, especially through the long, stiff hairs which we commonly call the "whiskers."

CHAPTER XVII.

BRANCH CHORDATA.

CLASSIFICATION OF MAMMALIA.

SUBCLASS I. — PROTOTHERIA.

THERE are two subclasses of mammals, the Prototheria and the Theria. The Prototheria nourish the young with milk. They also show that they are mammals by their hairy covering. But they reveal their relationship to birds and reptiles by the fact that *they lay eggs.*

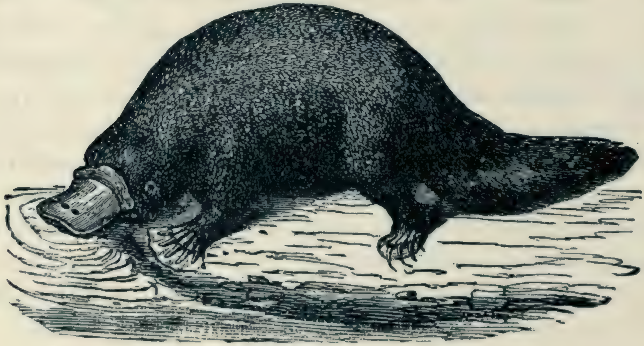


FIG. 151. DUCKBILL.
From Packard's *Zoölogy*, after Lütken.

In this subclass there is but one order, the Monotremata. The order contains but three or four species, and there are two chief forms, the duckbill and spiny ant-eater, both limited to Australia and adjacent islands.

The duckbill has a horny bill similar to that of a duck. Its habits are similar to those of a muskrat. It lives in water, and has holes in the bank, which it can enter beneath the water. The body is about as big as a cat's, though it presents a "squatty" appearance, the legs being very short. The feet are webbed and the tail is flattened. It is covered by a soft, fine fur. The duckbill has rudiments of teeth in the early stages of its life, but in the adult state neither the duckbill nor the spiny ant-eater has any teeth.

The ant-eater is of about the same size as the duckbill. The hairs are developed into strong, stiff, sharp spines. The bill is conical, and a small mouth at the end permits the extension of the slender tongue, with which it licks up ants like other ant eaters. It lives in rocky ground.

SUBCLASS II.—THERIA.

The Theria include all the remaining mammals. In this subclass the young are born alive, in the form of the adult.

The Marsupials. — Our only marsupial is the opossum. This odd animal is well known, at least by report, on account of its habit of feigning death when attacked. The marsupials get the name from their most marked characteristic, the possession of a pouch, or infolding of the skin of the abdomen. Two peculiar bones extend forward from the pelvis, toward the pouch; they are called the marsupial bones, as they support the pouch. The young are born in a very immature condition, and are transferred to the pouch, where they are nursed. The young are kept a long time developing in the pouch, and, after they become self-helpful, occasionally take refuge in the pouch. The opossum is almost omnivorous, eating insects, eggs, and birds, the teeth being of the carnivorous type. The opossum is a good climber, and has a hairless, scaly, prehensile tail.

Opossums are very tenacious of life, and it is commonly reported that after a "possum" has been severely pounded and "every bone in its body broken," it later gets up and crawls away. The following are some facts of structure

FIG. 152. OPOSSUM.
From photograph from *Recreation*, by permission of G. O. Shields.

that may explain such reports. First, the skin and hair make a thick protective covering, under which is usually a thick layer of fat. The chewing muscles extend far up on the top of the head, meeting in the middle line. The

skull is therefore well protected, so that it may receive a severe mauling and not be much the worse, except for external bruises. The opossum is of a low order of intelligence, and appears stupid, both when free and in confinement. It has not sense enough to become a pet.

The kangaroo is another well-known marsupial. The story of its development is about the same as that of the opossum, but the mode of life is different. The hind legs are excessively developed, and the animal hops with "record-breaking" power, seldom putting the feeble fore legs to the ground. When standing, the strong, muscular tail aids in supporting the body, forming a third leg, so to speak. The kangaroo is entirely herbivorous. There are many other marsupials in Australia, and, in fact, with the exception of the opossums, all the living marsupials are confined to the Australian region. Many countries yield fossil remains of marsupials, some of large size, showing that Australia contains the remnants of this peculiar, but once widely distributed race. It is further interesting to note that Australia has no other native mammals than the marsupials, except possibly the dingo, or wild dog, which some believe to have been introduced.

PLACENTAL MAMMALS.

All the mammals above the marsupials are born in a more mature condition.

The Edentates. — This order includes the sloths, armadillos, etc. They are not wholly toothless, as the name would indicate, but the teeth, when present, are simple or imperfect. They are mostly tropical, one armadillo occurring in southwestern Texas.

The sloths are herbivorous and tree-inhabiting. They climb, hanging under limbs by their hooked claws, and as

they proceed, strip off the leaves. On the ground they are almost helpless. The extinct slothlike megatherium was as large as a rhinoceros.

The armadillos have a scaly or horny development of the skin for protection; some have also the power of rolling themselves into a ball, still further securing safety.

The ant-eaters lack teeth; they secure insects by protruding the long, sticky tongue.

The Gnawers. — The gnawers, or rodents, are characterized by chisel-shaped incisor teeth, which keep wearing away at the tip and as continually growing from the root.

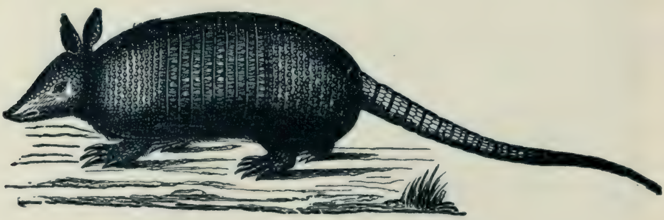


FIG. 153. NINE-BANDED ARMADILLO.
From Packard, after Lütken.

In all but the hares the incisors are two above and two below. There are no canine teeth, and there is a wide space between the incisors and the molars. They are chiefly herbivorous, and the digestive tube is long. They constitute the largest family of mammals, and are especially numerous in individuals.

The Hares. — The general characteristics of this family have been illustrated in the description of the rabbit. Besides our common gray rabbit, there are found in the Southern states the marsh hare and the water hare; in the North, the northern hare, which turns white in winter; on the Western plains, the big jack rabbit.

Porcupines. — The porcupines are distinguished by having sharp spines, which are really modified hairs, and are scattered among the longer hairs of the ordinary type so that the spines are ordinarily not very conspicuous. The spines are especially developed on the tail and on the posterior parts of the body. When the porcupine is attacked by an enemy, and especially if cornered, he turns his back toward his pursuer and draws the skin of the body forward, so that the quills point outward in all directions, and any attempt to seize him is met by a quick side stroke of the tail. The quills have a very sharp tip, near which are a series of backward-projecting barbs. They are also very loosely attached at the base. The result is that the quills readily pierce the soft skin of an enemy, become detached from the porcupine, and remain sticking in the wound. These facts are the sole foundation of the once widely accepted belief that the porcupine has the power to shoot his quills into his pursuer. In the West cattle often come in contact with porcupines and have their legs and noses stuck full of quills. On account of the backward-projecting barbs the quills cannot fall out, but keep working their way in deeper and deeper, making bad festering sores. On this account stockmen hate porcupines and usually shoot them on sight. In the lumber regions of the North porcupines also prove a nuisance, — in another way, however. They gnaw into the handles of axes, oars, or any wooden-handled implement, especially those that have been used, apparently for the sake of the salt that comes from perspiration. Hence tools are not left lying on the ground, but axes are stuck into trees with the handles standing far out, oars are laid up in bushes, etc. Porcupines are very stupid, being so well protected by their spines that they do not need to use their wits to escape an enemy.

Rats and Mice. — The rats and mice are of many kinds and of vast numbers. Man has adopted some kinds of animals, but these creatures may be said to have adopted man. They are universal attendants on civilization and are as cosmopolitan as man himself. The length of time that they have been associated with man is hinted at by the fact that the word for mouse, in essentially the

FIG. 154. CHIPMUNK.

From photograph from *Recreation*, by permission of G. O. Shields.

same form, is found in many languages. Though they have many enemies besides man, it seems impossible to exterminate them, for they are protected in many ways, especially by their nocturnal habits, and, as Coues says, by their very insignificance.

Beavers. — The largest rodent found in the United

States is the beaver. It has webbed hind feet and a broad, flat, scaly tail. All have read of its remarkable intelligence and skill in felling trees and in constructing dams. It was formerly widely distributed, but is now rare, owing not merely to the fact that it has been trapped for its fur, but also to the spread of civilization itself.

Squirrels. — The squirrels are a very interesting group, not only on account of their active and graceful movements,

FIG. 155. COMMON MOLE.

but also on account of their human trait of laying up provisions and their human mode of eating. Most attractive are the tree squirrels, including the fox squirrel, the gray squirrel, the red squirrel, and the flying squirrel. The woodchuck, prairie dog, and gophers live in the ground. The true gophers have large cheek pouches in which they carry out the soil in digging their burrows.

The Insect Eaters. — This order is best represented by our common mole, whose work of raising a ridge of sod is

familiar to all. They make these ridges in burrowing for earthworms and grubs, which are their main food. They are well fitted for digging by the very large front feet and strong muscles of the front legs. Since they live in darkness, the eyes have become rudimentary, sometimes concealed by the skin. The teeth are like those of a diminutive flesh eater. The nose is long, bare at the tip, and very sensitive. There are no external ears. The shrews are mouselike and are probably often mistaken for mice, as the front feet are not enlarged as in the moles; but the nose is more pointed, and one look at the teeth would show that a shrew is not a "gnawer." This order also includes the hedgehog of the old world, which has the hairs developed as sharp spines. The fact that both the hedgehog and porcupine have sharp spines leads to confusion. It is unfortunate that many writers are either uninformed or careless in this matter and further extend an already widespread error. The two animals are entirely distinct, and the following tabular statement may aid in showing their points of difference:—

DIFFERENCES BETWEEN A HEDGEHOG AND A PORCUPINE.

HEDGEHOG.		PORCUPINE.
Insectivora	Order	Rodentia
Conical points	Teeth	Chisel-shaped incisors
Insects, etc.	Food	Herbage
Not barbed	Quills	Barbed
Firmly attached	Quills	Loosely attached
Less than a foot	Size	Two feet or more
Old world	Habitat	Both old world and new

The Bats. — The bats of this country are insectivorous, and would undoubtedly be classed with the preceding order if they were not flyers. The wing is a fold of skin

supported by the arm and the excessively elongated fingers; the fold in our bats extends to and includes the tail. The thumb is free from the wing membrane and has a hooked claw by which the bat can hang, but usually when at rest it hangs head downward by the hooked claws of the hind limbs. Every one is familiar with the flight of our bats as they zigzag after insects. Bats are chiefly nocturnal. There is much superstition concerning them. There are in the tropics some blood-sucking bats, but ours are not only harmless but beneficial. Our bats hibernate in caves, hollow trees, etc. The large bats of the East Indies, known as flying foxes, are fruit eaters.

FIG. 156. RED BAT.

The Whales. — Though living continually in water, whales are true mammals; they bring forth their young alive and nourish them by means of milk. The fore limbs are developed into flippers. The tail is horizontally flattened, and its two lobes are called flukes. Whales are devoid of hair. The whalebone whale has in its mouth a long series of fringed baleen plates (whalebone), which serve as strainers. The whale ingulfs whole schools of crustaceans, jelly-

fishes, etc., and the water passes through these strainers and out at the sides of the mouth. Underneath the skin is a thick layer of fat which furnishes the whale oil. Such a layer of fat protects this warm-blooded animal in the icy water of the arctic seas. Since the discovery of our oil fields the whale fishery has declined. The "spouting" of whales is not due to a column of water, but to mucus and the condensed moisture of the breath.

Whales over fifty feet long are not often taken, though the sperm whale is sometimes seventy-five feet, and the "sulphur-bottom," found in the Pacific, is said to reach even a hundred feet. It is the largest living animal. Porpoises are smaller members of the same group.

The Sea Cows. — Some authors class these with the whales, but they are herbivorous animals, having grinding molars and a hairy covering. They seem to stand between the whales and the ungulates. They live in the mouths of large rivers; the manatee is found in Florida and on the west coast of Africa, the dugong in India and Australia. They are sometimes killed for their flesh, which is said to be very much like beef.

The Hoofed Mammals. — The horse and cow may stand as examples of this order, the ungulates. The hoofs are excessive developments of what correspond to our nails or the claws of other animals. In many forms the hoof encases the whole of the lower surface of the foot. It appears to be a special adaptation for the support of heavy animals, many of which have to run rapidly over rough or even rocky ground. The number of toes is typically five, though no living ungulate has more than four. They are all digitigrade, — that is, they walk on the toes. They are all herbivorous, with teeth adapted for grinding. This is a large order, and its members are of a large average size.

In its domesticated forms it is probably the most useful of any order to man, as from it are derived beasts of burden. Members of this order also furnish us with food (meat, milk, cheese, butter), leather, etc. The domestication of the horse, cattle, sheep, etc., dates so far back that we know not what were the wild forms from which they have descended. The ungulates are divided into two groups, according as the number of toes is odd or even, — the odd-toed group being called Perrissodactyls, and the even-toed, Artiodactyls.

The Perissodactyls. — These forms have an odd number of toes, as shown in the horse, rhinoceros, and tapir.

The Horse. — The horses now in this country are not natives, but were introduced from the old world; the Indians did not know the horse till after what we call the "discovery" of America. Still, America did have horses in earlier geologic periods, and the history of the development of the horse, as shown by fossil remains (largely found in this country), is exceedingly interesting. The earliest form was about the size of a fox, and had four well-developed toes in front, with a rudiment of a fifth and three toes behind. Later appears a form with four toes in front and three behind. Then came a horse about as large as a sheep, with only three fully developed toes in front, the fourth represented by a rudiment, but still having three toes in the hind foot. Later still the outer toe became reduced to a mere remnant. Then came a form about the size of a donkey, with three toes all around; the middle toe persisting and the two on each side becoming dwarfed. Finally, the one-toed horse was evolved, the single toe being the middle one of the five, that is, corresponding to our middle toes and middle fingers.

The Tapir. — The tapirs are found in South America and Sumatra. They have four toes in front and three

behind. The snout is prolonged, suggesting the proboscis of the elephant, but its relationship is plainly with the horse.

The Rhinoceros. — The rhinoceros has three toes all

Fig. 157. South American Tapir.

around. It is peculiar in having a horn on the top of the snout. In some species there are two horns, not paired, however, but one in front of the other. These animals are found in Africa and East India.

The Artiodactyls. — The artiodactyls, or even-toed ungulates, have either two or four toes. These are symmetrically arranged on each side of a median cleft; hence they are spoken of as "cloven-footed" animals. Lowest among the even-toed ungulates are the hippopotamus and the swine. A species of wild hog, the peccary, inhabits Central and South America, extending into Texas. It is a slender, active, fearless animal, in marked contrast to our inactive, fat-burdened domestic hog. The swine are omnivorous, the other ungulates are almost strictly herbivorous.

Except the camel, nearly all the artiodactyls have four toes, — two well developed and two rudimentary. The well-developed toes are the third and fourth, the first toe (corresponding to our great toe and thumb) being wanting. The second and fifth toes are small, but usually with distinct hoofs; they are shorter and back of the two main parts of the hoof. These rudimentary hoofs are commonly called the "dewclaws." They do not ordinarily reach the ground, and are of little if any use, except in the reindeer.

The Ruminants. — With the exception of the hippopotamus and the swine, all the even-toed ungulates are cud chewers and have complex stomachs. As an example, let us consider the cow. There are no upper incisors; grass and herbage are bitten or broken off by pressing the lower incisors against the hard, toothless pad of the upper jaw. The molars are well developed, and the lateral chewing motions of the jaw are well known. In keeping with this lateral motion, the ridges on the crowns of the molars run lengthwise in wavy lines. The stomach consists of four

compartments. When the food is cropped it is swallowed without chewing. It passes into the large paunch, or first stomach; when the ruminant lies down to rest, the soaked fodder is passed into the small second stomach, the honeycomb or reticulum, where it is formed into distinct masses and returned to the mouth for thorough mastication. It again goes down the gullet, this time to the third stomach, the psalterium, or manyplies, whence it enters the true stomach, or fourth stomach, sometimes called the rennet. The intestine is very long, between twenty and thirty times the length of the body. The ruminants need a large quantity of food, hence it is easy to see how it is of advantage to them to be able to gather their food quickly, retire to a place of concealment, and digest it at their leisure, as many of them are comparatively defenseless. The males of all the ruminants, except the camels, have horns, and in many species the females also possess them, though usually much smaller than those of the male.

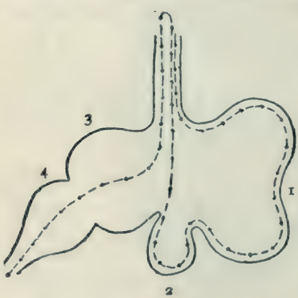


FIG. 158. DIAGRAM OF THE STOMACH OF A RUMINANT. Showing the course of the food. From Kingsley's *Comparative Zoölogy*.

The Hollow-horned Ruminants. — In cattle, sheep, goats, and antelopes, the horn consists of a bony core, covered with a layer of horn, which is not shed except in the case of the pronghorn antelope of our Western plains.

Sheep. — The rams have large, curved horns, which they use for butting when fighting. Our native sheep is the Rocky Mountain, or bighorn sheep, so named from its immense horns. These, in the old rams, become very much

battered. Hence arose the story, long widely accepted, that they jump down precipices, alighting on their horns. Since the ewes and lambs can go anywhere the rams can, the absurdity of the account is evident. They are remark-

Lamb. Ram. Ewe.

FIG. 159. MOUNTAIN SHEEP FAMILY.

From photograph of some of the author's trophies.

able climbers, walking securely on a narrow ledge, perhaps over a sheer precipice of a thousand feet, with the utmost unconcern. They are wary animals, usually having a sen-

tinel, commonly an old ram, posted on a high point of rock, on the lookout for enemies. They seem to expect attack from below, so the hunter tries to get above them. They stay most of the time above timber line.

Goats. — The Rocky Mountain goat dwells in equally inaccessible mountain tops. Its color is pure white, though its coat is usually dingy from the habit of sunning itself in a bed of dust. Its white coat seems odd for a wild animal. But when one sees it in its home, up among snow banks

FIG. 160. ROCKY MOUNTAIN GOAT.
From photograph of specimen mounted by L. L. Dyche, in *Camp Fires of a Naturalist*. By permission of D. Appleton & Co.

and light-colored rocks, it seems well adapted to its surroundings. It has small, smooth, black horns. Mountain goats are rather stupid animals. The main difficulties in hunting them are due to the steepness of ascent and the rarefied condition of the air.

The Buffalo. — The American bison, usually called "buffalo," is now nearly extinct. Buffaloes once roamed

in countless herds over the plains and prairies of almost all of the United States; to-day probably the only wild herd in the country is in the Yellowstone Park, and it numbers hardly more than fifty. There are probably a limited number in British Columbia. Once the mainstay of the Indians, furnishing them with food, clothing, and tents (tepees), they were doomed to give way before an advancing civilization.

The Antelope.—The prong-horn, or antelope of our Western plains, is a peculiar animal, the only member of its family. It stands between the cattle and the deer families. It has hollow horns, which are shed annually. The bony core is a projection from the skull and is never shed. It is very swift-footed and wary, keen of eye and nose. Like most of our wild ruminants, it has a white rump. When hunted it usually runs to a ridge and stops to watch. Instead of getting out of sight of its pursuer, its policy is to keep its enemy in sight, but at a safe distance. The antelope is rapidly disappearing and is doomed to extermination.

FIG. 161. ANTELOPE.
From *Forest and Stream*.

The Solid-horned Ruminants — Deer. — The deer family in this country includes three species of deer, and the elk, moose, and caribou. Except in the caribou, only the males have horns. The horns, which are solid, are shed annually,

usually in December or January. They grow out again, with an added prong for each of the first six or eight years. Till fully grown the horns, or antlers, as they are often called, are covered with a soft fur, and are said to be "in the velvet." When the horns are mature this skin dies

FIG. 162. WHITETAIL DEER. HORNS IN THE "VELVET."
From *Recreation*, by permission of G. O. Shields.

and peels off, the owner assisting by rubbing them against shrubs and small trees. The two common species of deer are the whitetail and the blacktail deer. The whitetail deer is probably identical with the Virginia deer or red deer. It is the most widely distributed form, extending from Maine to Florida, and westward to the Rocky Moun-

tains, usually keeping in lowlands. The term "red deer" is inappropriate, as all our deer are red when in their summer coat, turning grayish in the fall. The blacktail is Western, preferring mountains or hilly country. The tip of the tail is black. This deer is also called "mule deer," on account of its very large ears. The horns of the

FIG. 163. BLACKTAIL DEER.
From *Forest and Stream.*

two species branch differently (see Figs. 162 and 163). The elk (see Frontispiece) is larger than the other deer, sometimes weighing eight hundred and perhaps a thousand pounds. A bull elk surpasses any of the stags of the old world. Elk are being reduced in number and bid fair to be exterminated, since they cannot hide so cunningly as deer.

The deer family is peculiar in lacking the bile sac. Deer shed their coats, in the summer time being reddish, or "in the red," as the hunters say; while in the winter they are grayish, or "in the blue." In the summer the males of the elk and deer keep by themselves, ranging

FIG. 164. MOOSE.
From *Forest and Stream*.

high on the mountain sides, often upon the rocks near timber line, while the does and fawns are more likely to be found on lower slopes or in the valleys.

In hunting squirrels, the hunter has only two senses to guard against, sight and hearing. But in hunting deer the

hunter must not only keep out of sight and out of hearing, but must also avoid detection by a third sense, — that of smell. If he attempts to approach this game from the windward side, they are almost sure to detect him and to escape, often without his being aware of their presence, unless he afterward discovers their tracks.

The moose is an awkward-looking animal, with its long hump nose. The antlers are spread out into a flattened "blade" near the tips. The moose lives in marshy forests. There is a considerable number in northern Maine, Nova Scotia, Alaska, and in British Columbia. A few remain in Idaho, in the northwestern part of Montana, and in the region of Yellowstone Park. The moose and deer feed almost entirely on twigs and leaves, that is, they "browse," while elk feed to a considerable extent on grass, like our domesticated cattle.

The Camel. — The camel has but two toes, with large, soft pads. The hump is a storehouse of fat. They can go without water longer than most animals, but this is no more than might be expected of an animal accustomed to living in a desert country.

The Giraffe. — The giraffe is remarkable for the extreme length of its neck. Nevertheless, it has but seven cervical vertebræ, the same number that we have, the increase being due to the lengthening of the individual vertebræ.

The Elephants. — The elephants are essentially ungulates, having five toes, each incased in its own hoof; but on account of the peculiar development of the nose into a trunk, or proboscis, most authors place them in a separate order. The excessively long snout is flexible, very muscular, and serves as a hand in conveying food to the mouth. This arrangement seems especially desirable for an animal

with long, stiff legs and a very short neck. Even if he were not stiff-legged and short-necked, it would be inconvenient for him to dispense with the trunk so long as he retains the tusks. These are the long upper incisors, which are of solid ivory, the slight amount of enamel which originally covered the tips soon wearing away. Elephants are herbivorous and have one large grinding tooth in each half-jaw. The skull is not heavy in proportion to its size, as it has many large air spaces. The skin retains a few scattered hairs, with a distinct tuft at the end of the tail. Two species of elephants are found, one in India, the other in Africa. Still larger than the elephants were their (now extinct) relatives, the mastodon and the mammoth.

The Flesh Eaters. — The flesh eaters, or beasts of prey, are fitted for their life (1) by their activity; (2) by their sharp teeth, especially the long canines; (3) by the claws, usually sharp and strong; (4) by their color, usually in harmony with their surroundings. The lower jaw is so hinged that only an up-and-down, or true hinge motion, is permitted; this should be considered in comparison with the lateral jaw movements of ungulates and the gliding forward-and-back of the rodents. Instead of being flat-topped, the molars are somewhat like saw-teeth, the upper and lower shutting past each other like shear blades. The flesh eaters have simple stomachs and relatively short intestines, as the digestion of flesh is short and easy as compared with that of vegetable food. The senses are generally very acute. As there is considerable variation in adaptation to the conditions of life, let us consider four types of flesh eaters as represented by the cat, dog, bear, and seal.

The Cats. — Cats are distinguished from the other beasts of prey by having the claws retractile, that is, they can be

withdrawn into a sheath, where they are kept most of the time, the animal walking on pads developed on the next to the last joint of each toe. These pads enable the cats to walk noiselessly, and this is an important trait, as they capture their prey by lying in wait or by creeping near it stealthily, then suddenly pouncing upon it. In a bright light the pupils are reduced to a narrow vertical slit. In the dark they dilate widely; thus they are fitted for their nocturnal habits.

Our biggest cat is the cougar or puma, also called the American panther, and in the West known altogether as the mountain lion. Its body is about as thick as that of a sheep and somewhat longer, with a long tail. It is tawny brownish yellow above, paler beneath. Though fierce when wounded or cornered, it is a sneaking, cowardly creature, few instances being known of its attacking a human being. It follows mountain sheep and other mammals, ready to seize the young or the sickly or wounded adults. It is found from British Columbia to Patagonia. The wild-cat and lynx are smaller and are short-tailed, being in some localities called "bobcats." Other cats are the lion, tiger, leopard, jaguar, etc.

The Dogs. — Dogs have the nose more pointed than the cats. The claws are blunt and not retractile. The dog-like form includes the wolves, jackals, and foxes. Most of this group capture their prey by running it down, instead of by stealth as in the cat tribe, though the fox is rather catlike in this respect. Proverbial for his cunning, the fox remains in thickly settled districts, not disdaining birds that are domesticated. We have two species of wolves. The prairie wolf, or coyote, has a sneaking, cowardly disposition. When an Indian wishes to express his utmost contempt for an individual he calls him a coyote. The

timber wolf is larger and does considerable injury by killing calves and lambs. A bounty is paid for wolf scalps. Wolves are little to be feared in this country.

The hyenas are between the cats and the dogs. They have heavy shoulders and fore limbs, also strong jaws and

FIG. 165. GRIZZLY BEAR. FROM PHOTOGRAPH.
From *Recreation*, by permission of G. O. Shields.

teeth to crush bones. They are the scavengers among the beasts of prey, like the vulture among the birds of prey.

Both the cats and the dogs walk on the toes, hence are said to be *digitigrade.*

The Bears. — Bears walk on the whole flat of the foot and are therefore called *plantigrade.* Bears are less distinctly carnivorous than the above groups. They live largely on berries when they can get them. They eat many insects,

turning over logs and stones and devouring the beetles, worms, and larvæ. They are, in fact, omnivorous and not only in their food, but in their mode of feeding, resemble hogs. The ferocity of bears is greatly exaggerated. They are extremely shy animals, usually on the lookout for danger; even when feeding they look around at short intervals. One common mode of hunting them is to watch a carcass of some large animal. When a bear discovers such a "feast" he feeds greedily, and either stays in the neighborhood or returns regularly till it is all consumed. The hunter lies in wait or approaches when the bear is feeding, usually at dawn or at dusk. The approach must be made with the utmost care from the leeward, or the bear is gone without being seen. A bear has no wish to cultivate man's acquaintance. But a wounded bear is a most desperate and dangerous foe. He is quick on his feet and strikes like a prize fighter, a single blow from his mighty arm, with its long claws, often completely disemboweling a victim. In rare instances a bear, when discovered feeding, becomes enraged and shows fight. Aside from these conditions almost the only occasion when a bear "begins a fight" is when a female with cubs is met; even then she often ignominiously takes to flight. Though clumsy in appearance, the bear is a swift runner. In the fall bears usually become very fat. Through most of the winter they hibernate, or "hole up," as the hunters say, in a cave of rocks or under the roots of a big tree. North America has four kinds of bears: the polar bear; the grizzly, including the silvertip; the black bear, including the cinnamon bear; and the big brown bear of Alaska.

The raccoon is very much like a diminutive bear, not only in its plantigrade feet, but also in its food habits. Coons are shrewd creatures, and make good pets.

The Weasels. — These are by some placed with the bears, while others ally them to the cats. In this family are the weasel, mink, ermine, marten, ferret, otter, badger, wolverine, skunk. All are valuable for their fur. The weasel turns white in winter. Most of these have strong scent glands. Several of them are excellent swimmers and divers, living largely on fish. One otter lives in the sea.

The Seals. — The seals are fitted for aquatic life by having the hands and feet developed as paddles or "flippers," the limbs being very short. The sea lion can walk on all fours; others have the hind limbs permanently turned backward, forming a sort of "tail fin," so that they swim very much like the fishes, on which they feed. Seals are sometimes said to be *pinnigrade* (walking by fins) in contrast to the digitigrades and plantigrades. No seals inhabit the tropics. The seal grounds of the southern hemisphere have been depleted by indiscriminate killing, and the northern fields bid fair to meet the same fate.

The Primates. — This order, highest of all the mammals, includes the monkeys, apes, and man. There is a great range from the little squirrel-like marmoset to the massive gorilla, and from the horizontal-bodied, four-footed lemur to the erect biped, man. But structure is the basis of classification, and many of these lower forms have almost bone for bone and muscle for muscle similar to those of man. The higher apes are tailless. The form differs greatly, the facial angle of the ape being almost that of a dog, while the Caucasian has an angle of about 95°. As we approach man in the scale the body becomes more erect and is supported on the flat sole, instead of on the outer edges as in the lower forms. Man alone has a well-developed hand, and he distances all other forms in having the power of speech, although some authors think

apes have a language. The name *orang-utan* means "man of the woods." Anatomists do not agree as to which is nearer man, the chimpanzee or the gorilla. It must be borne in mind that in the animal world *classification is based on structure,* and that the zoölogical point of view does not take into consideration the intellectual, moral, or spiritual qualities.

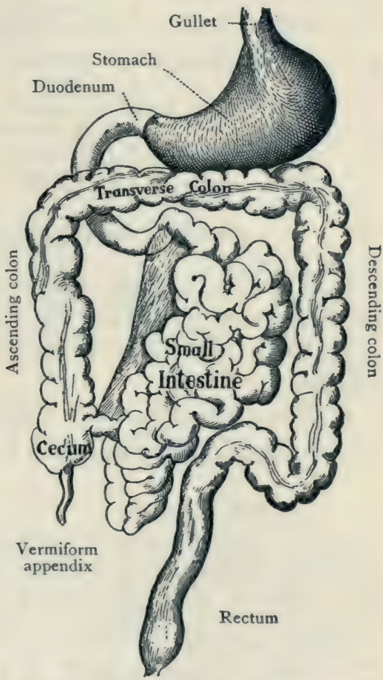


FIG. 166. STOMACH AND INTESTINES OF MAN.

Characteristics of Mammals.—(1) Mammals have a hairy covering. (2) The young are born alive. (3) The young are nourished by milk from mammary glands. (4) There is a diaphragm separating the body cavity into thorax and abdomen. (5) All have teeth set in sockets. (6) Two pairs of limbs are usually present. (7) There are usually seven cervical vertebræ. (8) The lower jaw articulates directly with the skull and not by the intervention of a separate bone (quadrate bone) as in birds. (9) There is an epiglottis covering the opening (glottis) to the windpipe. (10) The blood is warm, and of a nearly constant temperature. (11) The heart is completely divided by a partition into right and left halves.

CLASSIFICATION OF MAMMALS.

SUBCLASSES.		ORDERS.	
1. Prototheria		1. Monotremata	Duckbill and Spiny Ant-eater
2. Theria	(*Nonplacentals*)	2. Marsupialia	Opossum, Kangaroo
	(*Placentals*)	3. Edentata	Sloth, Armadillo
		4. Rodentia	Rabbit, Squirrel
		5. Insectivora	Mole, Shrew
		6. Cheiroptera	Bat
		7. Cetacea	Whale, Porpoise
		8. Sirenia	Sea Cow
		9. Ungulata	Horse, Cow, Deer
		10. Proboscidea	Elephant
		11. Carnivora	Cat, Dog, Bear, Seal
		12. Primates	Lemur, Ape, Man

CHARACTERISTICS OF CHORDATA.

1. There is a notochord, a long skeletal rod, a sort of forerunner of the backbone.

2. There are gill slits opening from the throat to the outside.

3. The central nervous system is a hollow tube and is wholly dorsal to the digestive tube.

CHARACTERISTICS OF VERTEBRATA.

In the Vertebrata the characters given for the Chordata are distinctly displayed, and a permanent backbone is developed. A cross section of a vertebrate shows two cavities (see Fig. 150), the dorsal containing the cerebro-spinal nervous system, and the ventral containing the digestive, circulatory, and respiratory organs. In the vertebrates a liver is always present. The nervous system is usually well developed.

Classification of Animals. — An early classification divided animals into two groups, the vertebrates, or the animals having backbones; and the invertebrates, those lacking a

backbone. A comparatively recent grouping is into Protozoa, or one-celled animals, and Metazoa, or many-celled animals. Each of these groupings simply characterizes one group (one system taking the lower end and the other the higher end of the animal series) and lumps off all the rest in one negatively named group. Neither of these systems pretends to do anything more than call attention to the presence or absence of a single feature of structure.

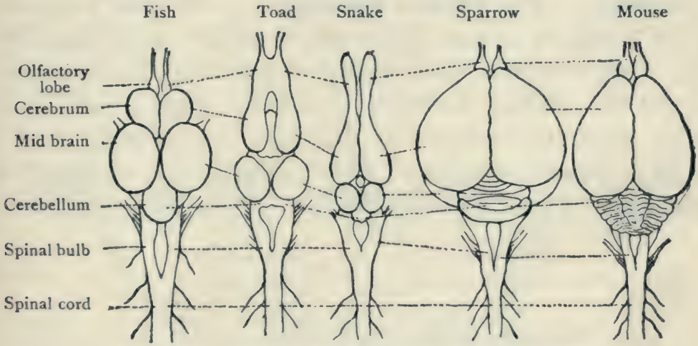


FIG. 167. DIAGRAM OF BRAINS OF VERTEBRATES.
From Kellogg's *Zoölogy*.

The Basis of Classification of Animals.— The basis of classification of animals is structure, only so many branches being recognized as there are distinct plans of structure. It is generally understood that the structure considered is that of the adult, since many animals change greatly during their development. But in some cases, especially of degenerate forms, the larval form shows, more clearly than the adult, the true relationship. Consequently embryology must be called in as an aid in classification. Fossils also clear up many doubtful points in classification.

CHAPTER XVIII.

BRANCH PROTOZOA.

THE ONE-CELLED ANIMALS.

Amœba. — The Proteus Animalcule. — One of the simplest forms of animal life is the Amœba. It is found in the slimy coating usually found on submerged leaves and stems in standing water, or in the slimy ooze resting on the mud at the bottom. If this ooze be examined under a high power of a microscope, amœbæ may usually be found, though occasionally one has to search for some time

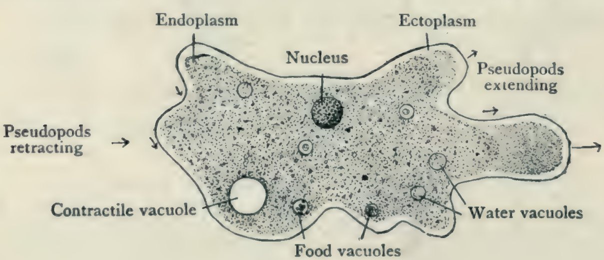


FIG. 168. AMŒBA.

before he is successful. And it is difficult for a beginner to be certain, at first, whether what he has found is really an amœba. An amœba is a speck of clear, colorless, jellylike substance called protoplasm, with a distinct, though delicate, outline. There can usually be discerned a clearer outer layer, the *ectoplasm*, and a more dense central portion, the *endoplasm ;* but there is no distinct line between the two. Sometimes one can see a more dense

appearing portion, the *nucleus*, and occasionally there appears a clear space, the *contractile vacuole.*

If the object is an amœba, it will usually soon betray itself by its motion. First there is a bulging out on one side, and this projection may be prolonged into a distinct lobe, called a *pseudopod.* The amœba may form several of these pseudopods at the same time, so that it may have little central body and nearly all of its substance may be in the pseudopods. These pseudopods may be extended and retracted without changing the place of the amœba. But more often after a pseudopod has been protruded, the rest of the body follows it, seeming to flow into it; by

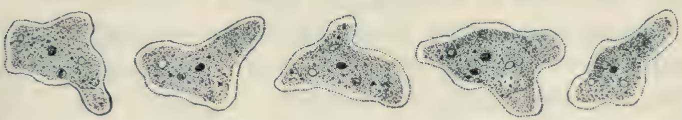


FIG. 169. AMŒBA: CHANGES IN FORM, DRAWN AT SHORT INTERVALS.

repetition of this process the amœba changes its place, and thus exhibits not only motion, but *locomotion.* If watched for some time the amœba may be seen to change its shape considerably and to make slow progress, sometimes for a considerable time in the same direction.

Patient watching may reveal how the amœba takes its food. If a small plant or animal cell or portion of such matter lies in its way, a pseudopod is pressed against it and it becomes embedded in the endoplasm. With any such food material there is usually taken a small amount of water. The space occupied by the water and absorbed food is called a *food vacuole.* Usually a number of these food vacuoles may be seen in an amœba. After a time the water and other matter disappear, having been digested and absorbed and assimilated into the substance of the

amœba. Occasionally a grain of sand, or other indigestible matter, is taken in; in this case it is finally passed out of the body, usually being left behind as the amœba moves on. There is no mouth; food may be taken in at any part of the surface. There is no stomach; the space occupied by the ingested food is an improvised stomach. There is no anus, residual matter being passed out at the point most convenient. Still, as the amœba moves about in search of food, the surface that happens to be foremost is likely to take in the new matter, and the part that is, for the time, rearmost serves as the place of exit. The amœba may be said to flow around its food, and to flow away from, and so leave behind, its waste matter.

The work of moving about involves the expenditure of energy. This energy is produced by the oxidation of the substance constituting the amœba. Oxygen is constantly being absorbed through the surface to supply this need, which varies according to the degree of activity. The oxidation of the matter of the body of the amœba produces carbon dioxid and water, which are passed off, invisibly, through the surface. The new food taken replaces the loss by such oxidation. This taking in of oxygen and giving out carbon dioxid is respiration, in its simplest form. In the oxidation heat is produced, which probably is given off to the water about as fast as it is produced in excess of the temperature of the surrounding medium. Actively moving amœbæ warm the water in which they move, as truly as we warm the water in which we are bathing, or the air in which we are performing active muscular work. And as we taint the air with our waste products and need a constant renewal of the surrounding air, so the amœba must not be confined too closely in a limited quantity of water that is sealed from the air.

The amœba shows that it has a sense of touch, for it frequently avoids solid objects with which it comes into contact, passing to one side. It has the characteristic termed *irritability*. This characteristic does not involve any special degree of sensitiveness, but simply the power to receive impressions through contact with external objects. If stimulated by slight electric shocks, the amœba may be made to withdraw its pseudopods and remain quiet in a spherical form. It is said to have contracted, and is said to be endowed with the property of *contractility*, but it is simpler merely to say that it has *changed its form*.

But the amœba does not always wait to be stimulated from without to make it move. It sometimes appears to move "of its own accord," as we say. That is, it is automatic, in the sense of self-moving.

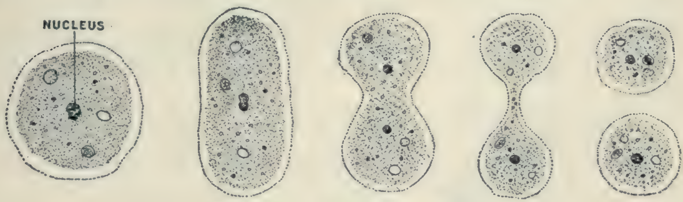


FIG. 170. AMŒBA DIVIDING.

If amœbæ are well nourished, they are likely to multiply. They do this by simple division. An amœba becomes constricted in the middle. The constriction increases until the individual is divided into two.

Encysted Amœba. — Sometimes an amœba, when subjected to drouth, or perhaps other unfavorable conditions, forms a tough outer wall, and remains in a quiet condition. The tough covering is called a "cyst," and the amœba is said to be "encysted." It may thus remain

dormant for a long time, until more favorable conditions return, when it ruptures the cyst, crawls out, and once more renews its former active life.

SUMMARY OF THE CHARACTERISTICS OF AMŒBA.

1. It *eats;* it takes in material through its surface from the surrounding water.

2. It *digests;* the material thus taken in is made soluble so that it can be used in building up the body of the amœba.

3. It *assimilates;* after suitable preparation the material is taken into the actual substance of the amœba; it is "made like," as the word "assimilate" signifies.

4. It *grows*, as a result of assimilation. Growth is the increase in size and substance of a living thing as a result of taking material from the outside and making it over into its own body. Growth should be distinguished from the mere increase in size of such dead objects as an icicle or a crystal by the accretion of more material on the outside.

5. It *moves;* it has power, not to change its bulk, but to change its shape. It is able to rearrange its particles, which is what is meant by the term "contract." Contractility does not mean ability to occupy less space. Distinction must be made between "motion" and "locomotion"; when an amœba extends a pseudopod and then withdraws it, this is motion; when an amœba changes its place, or moves on, this is not only motion, but also locomotion.

6. It *breathes;* the energy of motion is maintained by a process of oxidation going on within the substance of the amœba. Oxygen is absorbed through the outer surface and unites with the materials of the body of the amœba. Its energy is furnished by this oxidation as truly as the

energy by which a train is moved is furnished by the burning (oxidation) of coal in the engine.

7. It *produces heat;* heat is another form of energy which always results from oxidation. We are always producing some heat, even when we are as quiet as possible, and we know that when we are more active we breathe faster and produce more heat. So with the amœba. But the amœba should be classed with the so-called "cold-blooded" animals. It should be noted that not only do all such animals have a rather low temperature, but it is a variable temperature and usually only slightly above the temperature of the surrounding air or water. The amœba is constantly producing heat, but gives it off to the water about as fast as it is made.

8. It *gives off waste matter*, i.e. it *excretes.* All oxidation produces waste matter. Oxidation of wood or coal produces carbon dioxid, water, and ashes. Our breathing produces carbon dioxid, water, and other wastes which we throw off continually. The carbon dioxid, water, and other wastes thrown off by the amœba are small in amount, and, being invisible, pass out into the water unnoticed.

9. It *feels;* when a foreign body comes into contact with an amœba it usually moves. A slight electric shock causes it to assume the spherical form. There is good evidence that amœbæ have the sense of touch. They also seem responsive to light and heat.

10. It *reproduces its kind;* this we have seen is done in the simplest way imaginable; that is, merely by separating into two parts, each of which is then a complete individual. Multiplication takes place by division.

Paramecium, the Slipper Animalcule. — The slipper animalcule is usually to be found in the water collected for amœbæ. In aquariums where clams have been kept,

or in vases where flowers have been standing for some time, a film of scum is likely to appear. Just underneath this film is a good place to look. Often the naked eye may detect small white objects moving about. These are paramecia. On examining some of the water with a low power of the microscope, one discovers that these tiny white specks are oval or elliptical, that they swim actively,

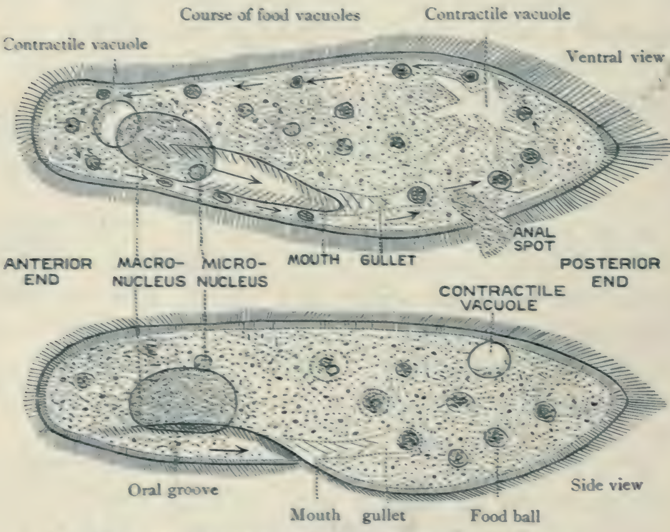


FIG. 171. PARAMECIUM, THE SLIPPER ANIMALCULE.

usually with the same end foremost, and that when they run against an obstruction they back off quickly. They evidently have the power of moving and the sense of touch. Looked at with a higher power, the shape may be determined more definitely. They are somewhat flattened, and one end is more pointed than the other. The difference between the clear ectoplasm and the more granular endoplasm is more marked than in the amœba

There is also a rather distinct layer, or cuticle, forming the outer layer of the ectoplasm. The whole surface is covered with small, hairlike projections called cilia. These are prolongations of the protoplasm which makes the body of the paramecium. These have the power of actively lashing back and forth, acting like so many paddles, by means of which the paramecium swims. At the more pointed end, usually kept in the rear, there is a bunch of longer cilia, which seem to serve as a rudder. Sometimes the animal reverses its direction and proceeds with the pointed end foremost, but ordinarily only for a short time, to back out of a tight place and to get a new start in another direction.

How Paramecium Eats. — Along the flat surface is a groove, which at one end forms a blind passageway dipping into the body. Both the groove and the tube, which is a gullet, are lined by cilia. By their vibrations these cilia collect small one-celled plants and animals, or other particles of organic matter, which accumulate at the inner end of the gullet. From time to time this inner end is cut off by constriction, and a collection of food particles, with some water, is pushed into the soft protoplasm of the body. It then is what is termed a food ball, or sometimes the space with its contents is designated a food vacuole. These food vacuoles may be regarded as so many improvised stomachs. The masses slowly rotate around in the body in the manner indicated by the arrows in the accompanying figure. At a point about opposite their starting-point any undigested residue is expelled through a weak place in the wall, there being no permanent anal opening.

Excretion in Paramecium. — There are usually two clear spaces in a paramecium, one near each end. These may

be seen to contract at tolerably frequent intervals, apparently discharging liquid to the exterior. Around each of these "contractile vacuoles" is a series of radiating canals. After the vacuole has become obliterated by emptying its contents, it is gradually filled again by these surrounding canals, which get watery material from the various parts of the body. Thus certain waste material is thrown out.

The Nucleus. — Paramecium has two nuclei, a larger body called the macronucleus and a smaller called the micronucleus.

How Paramecium protects Itself. — In the outer part, or cortex, are many small sacs, each containing a tiny thread. When a paramecium is irritated, it discharges these thread-cells, which appear to produce a stinging or benumbing effect on small animals.

Multiplication of Paramecia. — Like the amœba and the vorticella, the paramecium forms new individuals by division. The constriction is transverse, at about the middle, and finally separates the one into two. Both the macronucleus and the micronucleus divide, a part going with each half, which soon after separating becomes a complete paramecium.

Vorticella, the Bell Animalcule. — Another interesting protozoan is Vorticella or the bell animalcule. It is found on submerged stems and leaves in stagnant water, sometimes appearing like a delicate white fringe. Under a low power of the microscope a vorticella is seen to be bell-shaped, attached by a slender, flexible stalk, which joins the handle end of the bell-shaped body to some solid object. When the animalcule is disturbed, the stalk becomes coiled, jerking the body up close to its support, where it is much more secure than when extended.

Examination with a higher power shows more of the structure of the body. The bell-shaped body is not hollow, but is made up of protoplasm. Across the mouth of the bell is a disk, which is slightly narrower than the mouth of the bell. Between the disk and the rim of the bell is a circular groove. At one point the groove dips down into the body of the bell, forming a mouth and a gullet. The borders of the disk and the bell are fringed

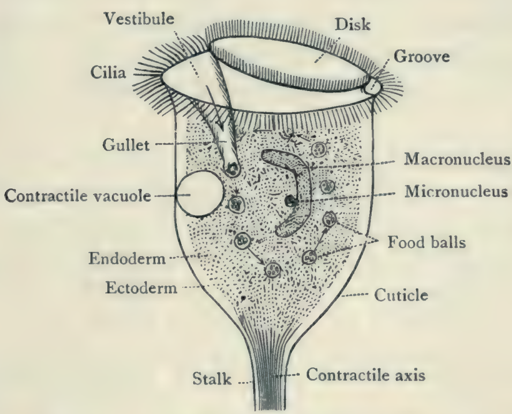


FIG. 172. VORTICELLA, THE BELL ANIMALCULE.

with cilia, which by their vibrations create water currents and thus accumulate food material in the inner end of the gullet. The food material consists largely of minute plants and animals or fragments of larger forms. As in the paramecium, the collection of food particles becomes pushed farther into the body, becoming a food ball, or food vacuole, which, with others preceding and following, rotate around the body in regular order. At the outer end of the gullet is a space called the vestibule. Into this any undigested residue is passed, and thus swept out by the

currents maintained by the cilia. There is also a contractile vacuole, which is near the vestibule and empties into it. The vorticella has a C-shaped nucleus.

How Vorticella protects Itself. — When a vorticella is disturbed it is at once jerked up close to its mooring by the coiling of its stalk. At the same time the body changes its shape. The disk is drawn in, the rim of the bell turns in, the cilia are inclosed, and the body becomes pear-shaped or even spherical, there being no opening left at the free end. After the disturbance has ceased, the stalk elongates, the bell opens, the disk protrudes, the cilia extend, and the operations of active life are all resumed.

Development of Vorticella. — Vorticella multiplies by longitudinal division. For some time two bells are attached to the stalk, but one finally breaks loose and swims away by means of its cilia. Later it becomes attached and develops a stalk.

GENERAL CHARACTERISTICS OF PROTOZOA.

1. The protozoans are the *simplest* animals. Most of them are one-celled. As a group, they are the smallest of animals.

2. They are the *most numerous*, in individuals, of any branch of animals. It is not true, as commonly believed, that every drop of water swarms with animal life. One would find few animalcules in ordinary well or spring water. But they usually abound in stagnant water. There is room for vast numbers of these lowly forms which occupy so little space.

3. They *multiply the most rapidly* of all animals. In most cases multiplication consists simply of division into

two equal parts, each of which is very soon a complete individual, ready again to divide in the same manner. Their great number is due to their rapid multiplication, to their small size, which makes it easy for them to find hiding places, and, further, to their complete adaptation to the conditions in which they live. Multiplication does not depend wholly on division. There is occasionally what is called "conjugation"; that is, two individuals come together and more or less completely fuse. At any rate, it seems to be proved that the species could not continue to live indefinitely without the occasional occurrence of conjugation. And this is supposed to be true of most of the Protozoa.

4. They are the *oldest* of animals; that is, they are supposed to have been on the earth longer than any other kind of animals. We find their remains in very early geologic formations. Some of them are supposed to have changed but little as time passed, the conditions of their surroundings being comparatively stable, while other groups of animals have been greatly modified by changes in their surroundings.

5. They are the *most independent* of animals. The conditions of their lives are such that they could live without the larger animals, while many of the latter could not live without them.

Kinds of Protozoans. — There are many kinds of protozoans, some of them widely different from any of the three forms we have studied. Some are parasitic. One of the parasitic forms causes malaria when introduced into the blood by the proboscis of a mosquito. Some protozoans, instead of having cilia, possess a few longer vibratile projections called flagella. In the one-celled forms there is usually one flagellum, or, at most, two. But the colonial

protozoans are composed of several or many cells, each of which may have a pair of flagella. Thus there are three principal modes of locomotion among protozoans: (1) slow creeping by means of pseudopods, as in amœba; (2) swimming by cilia, as in paramecium; (3) more active swimming by flagella, this mode being not very unlike the second.

The Shell-bearing Protozoans. — Many protozoans have shells. Some of these shells are composed of lime, others of silica, while still others are formed of grains of sand which the protozoan glues together by a secretion from its protoplasm. Most of these shelled forms live in the ocean. Some of the shells are borne where we should expect them, on the outside, the animal being able to withdraw into the shell and project again at will through an opening. But in many the animal cannot thus withdraw itself completely into the shell. Many of the shells are perforated by numerous minute openings, through which fine threads of protoplasm are extended, these projecting threads sometimes forming a network outside of the shell. In many forms the protoplasm increases in amount, flows out of the main opening of the shell, and forms a new shell, larger than the old one, but attached to it. In this way it proceeds, making a series spirally arranged, similar in general appearance to a spirally coiled snail shell, or the chambered nautilus.

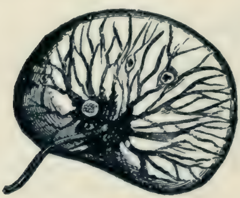


FIG. 173. NOCTILUCA.
A phosphorescent marine protozoan.

Chalk. — One of the most abundant and best known of geologic formations is made by protozoans. Chalk is made up of the shells, such as above described, of a kind of protozoan known as Globigerina. Myriads of these protozoans live in the ocean. When they die, their skele-

tons slowly settle to the bottom. Dredgings from the bottom of the Atlantic Ocean contain a gray mud which, under the microscope, is found to be largely composed of these shells. So where we find chalk rock on land, we know that region was once the bed of the ocean. This once soft mud has become hardened, by drying or by pressure, sometimes by both, into hard rock, a variety of limestone known as chalk. A generation ago the carpenter and the schoolboy used a rough broken lump of the chalk rock. The ordinary school crayon, however, usually contains no chalk. Any one who has used the old lump chalk will recall that occasionally he struck a hard, flinty place, due to the mixture of other material.

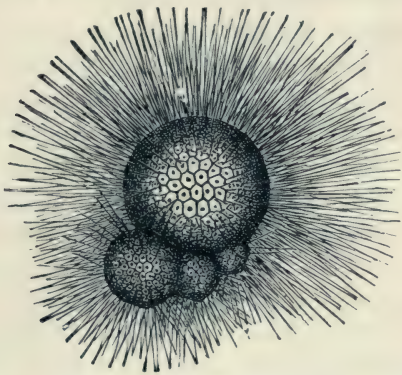


FIG. 174. A SHELL-BEARING PROTOZOAN (GLOBIGERINA).

From Packard.

Silicious Earth. — Other kinds of protozoans form their shells of silica. Beds of this material are found in various parts of the world and are used as polishing material, under the names Tripoli, Barbadoes earth, etc. Many of the shells of silica are exceedingly beautiful in form.

Distribution of Protozoa. — All protozoans are aquatic, though some might seem to be exceptions, living as they do in damp moss; but they are probably in thin films of water on the surface. Protozoans are the most widely distributed of animals, occurring almost all over the globe, in fresh water and in the ocean, in lakes and rivers, ponds and creeks, pools and ditches. In the ocean they are more abundant in shallow water, but are also found at considerable depths and at the surface of the deeper seas.

The Importance of Protozoa. — Protozoans are highly important in two respects: (1) they have contributed much to rock-making, and are still making deposits on the ocean bottom; (2) as a source of food to the animals of the ocean, it is difficult to overestimate their importance. In countless myriads they serve as food for animals somewhat larger and higher in the scale than themselves. These animals, in turn, are the food for still higher animals. The protozoans, then (with the protophytes or one-celled plants), may truly be said to be the food foundation of all the higher marine animals.

PROTOZOA AND METAZOA.

Protoplasm. — Protoplasm is the living substance of animals and plants. It is a clear, jellylike substance, which does not dissolve in water nor readily mix with it. When seen in water its outlines are usually quite distinct. It may appear more or less dotted on account of various kinds of matter suspended in it. An amœba is a mass of protoplasm, and the properties of protoplasm were considered in connection with amœba. Protoplasm has the power of *movement*, is capable of being stimulated, *i.e.* is *irritable*, it *eats*, *grows*, *breathes*, throws off waste matter, or *excretes*, and has the power of *reproduction*.

Protoplasm is killed by very high temperature, killed or its activity checked by low temperature, and, in general, requires the conditions that we usually recognize as necessary for life.

In its chemical composition protoplasm is exceedingly complex. Protoplasm is a living substance, and any attempt to analyze it kills it; hence its exact composition cannot be known. But the dead material left when it has been killed can be analyzed, and consists largely of a substance called proteid. This consists of carbon, hydrogen, oxygen, and nitrogen, with some sulphur, traces of iron, and compounds of phosphorus, potassium, calcium, and magnesium. Protoplasm seems to be a very unstable compound, as we should naturally expect from its complexity. Then, too, in its life and growth, it is constantly changing, and, undoubtedly, changes more or less in its composition from time to time.

The Cell. — Sometimes protoplasm occurs in a considerable mass, without any separation into distinct parts. But usually it is found in more or less distinct particles, and these distinct particles of protoplasm are called "cells." There may be a cell wall distinct from the mass of protoplasm, but this is not essential to a cell. Within the cell is a more dense appearing portion called the "nucleus." A cell living independently tends to be spherical, though since it has the power of changing its shape, it often departs from the typical form. When an amœba goes into the resting stage it assumes the spherical form.

Protozoa and Metazoa. — The protozoans are typically one-celled animals. The other animals are many-celled and are called metazoans. Their greater size is not due to their having larger cells, but to the increased number of cells.

Development of Metazoa. — Every metazoan begins life as a single cell (except in multiplication by budding). It starts as an egg (ovum or egg cell), having very much the same characteristics as an amœba. After being fertilized it soon divides into two parts, but these halves, instead of separating, as in the case of the amœba, remain together. These halves divide into quarters, and so on, into 8, 16, 32, 64, 128, etc., parts, until they become too numerous to be counted. After a time these numerous cells, still remaining together, arrange themselves in the shape of the animal that produced the egg cell.

Division of Labor in Communities. — A solitary backwoodsman has to do everything for himself. He gets and prepares his own food, provides needed shelter, makes his own clothing. But if he has a partner, there is sure to be some division of their labor. One can do some things better than the other, and they find that it is advantageous for each to do what he can do best. In an Indian family the men do the hunting and fighting, while the squaws prepare the food, dress the hides for clothing and lodges, etc. It is hardly necessary to call attention to the saving of time that results from such a division of labor, or to note the finer quality and finish of the various articles of common use when they are made by one who acquires skill by the constant practice which comes from devoting himself entirely to one kind of work. It is evident that no one man can do many things and do them all as well as when the work is divided.

Physiological Division of Labor. — An amœba does everything for itself. Of course it lives very well in its simple way, and is well adapted to its mode and place of life. But it does too many things to do any of them very well. It can move but slowly, it is dull of sensation, etc. Suppose that, when an amœba divides, the two parts remain

adhering to each other, and that it divides again, making four parts, and each of these divides, making eight parts remaining in one mass. It is easy to see how one might attend to the moving, another to the work of feeling, a third to eating and digesting, a fourth to breathing, a fifth to the work of dividing for the spread of the species, while the other three became more or less flattened and spread out over the others to protect them. This will serve to give an idea of what actually takes place when the egg cell of a metazoan has, by division, become a many-celled mass. Each cell has primarily all the characteristics common to an amœba, — that is, they all have power to move, eat, digest, feel, breathe, divide. But such a large mass would be unwieldy unless it had some support; hence some cells may, to the advantage of the whole, become harder and stronger to hold the soft cells in place. In this now heavier mass there is more danger of mechanical injury to the outside, and the outside layer by hardening will serve to protect the inner, more delicate cells from harm. If the outside cells harden, the animal will no longer be able so well to absorb oxygen for the interior cells, nor can it now take in food at any point. Special arrangement must be made to take oxygen and food into the interior, where soft cells can do the work of preparing it for use in the body. These inner cells have now more work than before, for they must prepare the material for building and maintaining the cells that have given up their power of digesting that they might fit themselves for protection. In proportion as any given cell devotes itself to one kind of work, it must lose more or less the ability to do the other kinds of work that it primarily could do. This is what is meant by physiological division of labor. All the cells resulting from the division of a metazoan egg

cell are at first essentially alike in structure and function. To fit themselves for the different kinds of work that they have to do, they *grow different.* This growing different is called *differentiation.* Each becomes fitted for one special work; this is *specialization.*

Tissues. — In the higher metazoans there are many cells devoted to each of the different kinds of work to be done. This we should naturally expect, for in such a body there are myriads of cells, but only comparatively few kinds of work. As has already been made clear, an amœba can do nearly all the kinds of work that any animal can do, though in a much simpler way. The functions of animals are summed up in saying they move, feel, eat, grow, breathe, protect themselves, and reproduce their kind. Stated more formally, the functions of animals are included in the processes of *motion, sensation, support, protection, reproduction, and nutrition* (nutrition including *digestion, absorption, circulation, respiration, and excretion*).

For instance, muscle cells are cells devoted to the work of motion; they have largely given up the other functions that they originally possessed. The nerves have lost the ability to change their form, in devoting themselves to the special work of sensation. So, too, with the cells of the supporting and protective tissues.

A *tissue* is a group of cells having the same structure and function.

An amœba consists of a single cell, but it can do a number of kinds of work. A tissue consists of many cells, but they all do the same kind of work. In other words, an amœba is simple in structure, but complex in function; a tissue is complex in structure, but simple in function.

Organs. — In addition to the differentiation of cells into tissues, there is a still further division of labor by having

certain distinct parts of the body devoted to a special work; for instance, the hand is adapted to the work of grasping; it is an *organ* and its special work, or *function*, is prehension. But the hand is composed of several kinds of tissues. It is supported by bony tissue, the muscular tissue gives motion to the fingers, the nerves are composed of nervous tissue, connective tissue makes up the tendons and part of the muscle, and the skin is another kind of tissue. In addition there is usually some fat, which is considered a still different tissue. The higher animals are *organisms*, — that is, they are made up of organs, each of which has its special function to perform. In other words, each organ works for every other organ in the organism, and every other organ works for it.

The Colonial Protozoa. — This name is given to the protozoans that have more than one cell, some of them being actually many-celled. The simplest of these protozoans are little more than an aggregation of cells, each of which leads a nearly independent life, doing its own digestion, etc. There is almost no division of labor among them. Others form a true colony, and there is a rather gradual series in development until in the higher forms there is a division of labor approaching that found in the simpler Metazoa. The cells in the simpler colonial protozoans lead lives so nearly independent of their associates that we might imagine the colony falling to pieces and each cell again taking up an independent life, like that of the amœba. Not so, however, with the metazoans. After their differentiation in structure and specialization in function they are so modified that they could no longer live independently. In developing one function each cell has neglected other functions till now it is no longer able to perform them. In other words, it has become *dependent*.

Each cell lives and works, not merely for itself, but for all. In their coöperation these units of a lower order have become so united as to form "a unit of a higher order," as the mathematician expresses it.

The cell is the unit of structure in animals, and where the cells unite and specialize they form a many-celled *individual*, in the strict sense of the word, — that is, it cannot now be divided without destroying the life of the whole complex individual.

There is one exception: the egg cells can, and do, live separately. This is their work, to separate from the body as a whole, for the express purpose of growing into new individuals.

CHAPTER XIX.

BRANCH PORIFERA.

THE SPONGES.

The Simplest Sponge. — The simplest sponge is a vase-shaped body attached by the base. It is hollow, and has an opening (osculum) at the free end. Through the wall are many small holes, and water is constantly entering these holes (inhalant pores) and passing out of the mouth of the vase. The cause of this current is the vibration of many flagella, which project inward from the cells lining the cavity. This current of water brings oxygen and food, consisting of minute plants and animals, and remains of larger animals and plants. The vaselike body is supported by a large number of three-rayed spicules, embedded in the wall of the vase. These are composed of carbonate of lime, and they constitute the skeleton, making the body fairly firm, and yet leaving it flexible and elastic. An outer layer of cells constitutes the ectoderm, the lining cells are the endoderm, while between these is a thin layer called the mesoderm, in which the spicules are embedded. (See Fig. 176.)

FIG. 175. SIMPLE SPONGE, MARINE.

Water enters minute holes in the sides and passes out of the opening at the top of the tube.

More Complex Sponge. — Somewhat higher is a sponge that is vase-shaped, or cylindric, in which the inhalant

pores do not lead directly into the main cavity (as shown in Figs. 176 and 177), but do so indirectly. The cells bearing the flagella, instead of lining the main cavity, are here in the radiating canals that open into the main cavity, and receive the water through cross openings from the incurrent canals. As in the simpler sponge, there are supporting spicules in the walls.

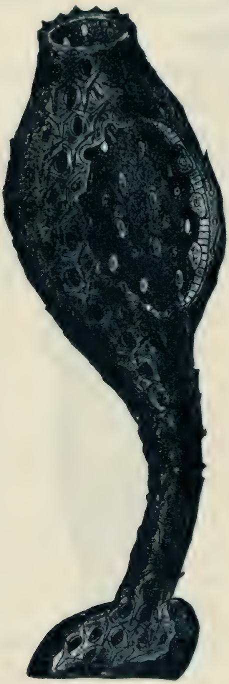


FIG. 176.
ONE OF THE SIMPLEST SPONGES, *Calcolynthus primigenius.*
(After Haeckel.)
A part of the outer wall is cut away to show the inside. — From Jordan and Kellogg's *Animal Life.*

The Highest Sponges. — The general plan of structure of the highest sponges may be illustrated by Fig. 178. The most noticeable peculiarities are two: (1) The cilia are limited to certain cavities, or enlargements, along the course of the passages from the outside to the main cavity. These cavities are called the "ciliated chambers." (2) The whole sponge is no longer a vase or cylinder, but a mass, in which the cavities are less conspicuous. This is due to the increase of the middle layer, or mesoderm, a gelatinous mass of cells. As before, the outer layer is the ectoderm, and the lining the endoderm.

Kinds of Skeletons.— Sponges may be classed, according to the nature of their skeletons, into three groups:—

1. Calcareous sponges, whose skeletons consist of

spicules of carbonate of lime, as seen in the simple sponge described. These spicules have various forms, but the three-rayed form is most common. They often resemble crystals.

2. The silicious sponges, with spicules of silica or flint. These skeletons often appear to be made of spun glass, and many of them are of great beauty, one of the most noted being the Venus's flower basket, found about the Philippine Islands.

FIG. 177. CROSS SECTION OF SIMPLE TUBULAR SPONGE.

Showing (1) three-pointed spicules (skeleton), (2) cilia which bring in water through (3) the holes in the sides of the tube.

3. The horny sponges, or sponges of commerce. These skeletons are composed of a substance called *spongin*, whose chemical composition resembles that of silk. Its fine, threadlike fibers branch and interweave, forming a feltlike structure, with which all are familiar. Its chief value consists in its absorbing power, and this, in turn, depends on its softness, fineness, and elasticity. Its durability is also a factor in its value. Some sponges have both silicious spicules and horny fibers.

The Commercial Sponge at Home. — If one could "call upon" one of these sponges, he would find it attached to rock at the bottom of a warm sea. He would see a roundish mass with a smooth exterior, in color and finish not unlike a dark-colored kid glove. He might see several large openings, from which currents of water are emerging, bearing carbon dioxid and other impurities. Over the surface he might discover smaller holes, into which the water flows, bearing oxygen and food. If he were to dis-

turb the sponge, these smaller openings would close, and perhaps the larger ones also. If he now tried to pick it up, it would be found firmly attached. Effort to detach it by pulling would probably crush it, and show that the whole has about the consistency of beef liver. It is easy to squeeze out all of the soft tissue and leave the elastic skeleton.

Source of Commercial Sponges.—The most valuable of the sponges of commerce come from the Mediterranean; many also come from the Red Sea, Florida, and the West Indies.

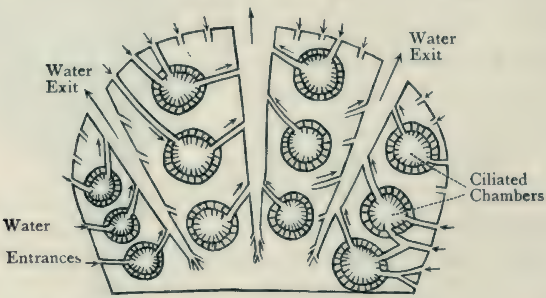


FIG. 178. DIAGRAM OF A COMMERCIAL SPONGE.

Collecting Sponges. — Sponges are collected by divers, or by the use of rakes, or by dragging hooks. They are piled on shore to allow the soft tissues to decay, after which they are washed, dried, sorted, trimmed, and shipped to market. The finer ones are usually bleached. Sometimes, in trimming away the base where they are attached to the rock, enough is cut away to leave a large hole; this is the lower end of the cloaca, or main cavity.

Fresh-water Sponges. — Most of the sponges are marine, but there is one family of sponges in fresh water. It is not uncommon to find them in lakes and rivers, where they

form a coating on logs and rocks, usually greenish or yellowish green. In still water they branch and may reach considerable height, but in swift streams form a low, spreading mat. They are of no commercial value. Sometimes in reservoirs supplying drinking water they give an unpleasant taste to the water.

Relations of Sponges to Other Animals. — None of the larger animals eat sponges. This may be due to the presence of the sharp spicules, or to an unpleasant taste or odor. Many small animals bore into or crawl into them, some for a safe hiding place, doing no direct injury to their host. Others are perhaps parasitic. While no sponge is a parasite, some injure shells, as oysters, by boring into them. Certain sponges are found only on the shells inhabited by hermit crabs, where they pay for their transportation by concealing their bearer.

Reproduction and Development of Sponges. — Sponges have two ways of multiplying, — by budding and by eggs.

In budding, a group of cells, called a "gemmule," is formed, which becomes detached, and develops into a sponge. Fresh-water sponges form these gemmules in the fall. The gemmules lie dormant over winter, and begin growth in the spring.

Sponges produce eggs. These eggs are cells, which are produced by the middle layer of the sponge (mesoderm). Other cells, called sperm cells (or sperms), are produced by some other part of the mesoderm, or perhaps by the mesoderm of another sponge. After the egg cell is fertilized by the sperm cell, it begins to divide, and forms a number of cells which cohere. Part of these cells have cilia, and by their vibration the embryo sponge swims about, until finally it settles, attaches itself, and remains fixed the rest of its life. While it is small and free, the

vibration of cilia propels it through the water; after it becomes attached, the vibration of cilia creates water currents, which bring it food and oxygen.

Rank of Sponges. — The sponges are many-celled and evidently higher than the colonial protozoans. But there is no high degree of differentiation of parts. The cells bearing flagella and the egg and sperm cells are different from the others. But there are no special distinct organs for the performance of special functions. In comparing them with other forms, it may be seen that they are plainly the lowest of the metazoa.

CHAPTER XX.

BRANCH CŒLENTERATA.

[This branch includes the Hydroids, Jellyfishes, Sea Anemones, and Coral Polyps.]

Example. — The Fresh-water Polyp, Hydra.

Naked-eye Appearance of Hydra. — In examining a jar of aquatic plants one may find attached to them slender cylindric bodies about half an inch long and of the thickness of a needle. Extending from the free end are several fine, threadlike tentacles, which may be as long as the body itself. Hydras are often white or colorless, but occasionally brown or green ones are found. If undisturbed, the body and tentacles may occasionally sway gently to and fro. If disturbed, a hydra usually shortens until it is a tiny ball. The tentacles also shorten until they look like a circle of tiny buds.

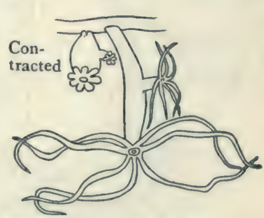


FIG. 179. HYDRA EXTENDED.

Structure of Hydra. — Microscopic examination is required to learn much of the structure of hydra. The cylindric body is hollow, and the hollow extends through the tentacles, which are closed at their tips. Above the circle of tentacles rises a cone-shaped body called the hypostome, at the apex of which is the mouth. The body wall consists of two layers, the outer being the *ectoderm*, and the inner the *endoderm*. Between these two is a layer called the mesoglœa.

The Ectoderm. — The cells of the ectoderm are clear, and more uniform in size than those of the endoderm. At their inner ends they are narrower, and usually end in slender prolongations, which bend at a right angle to the main axis of the cell, and help make a sort of middle layer between the endoderm and ectoderm. These prolonga-

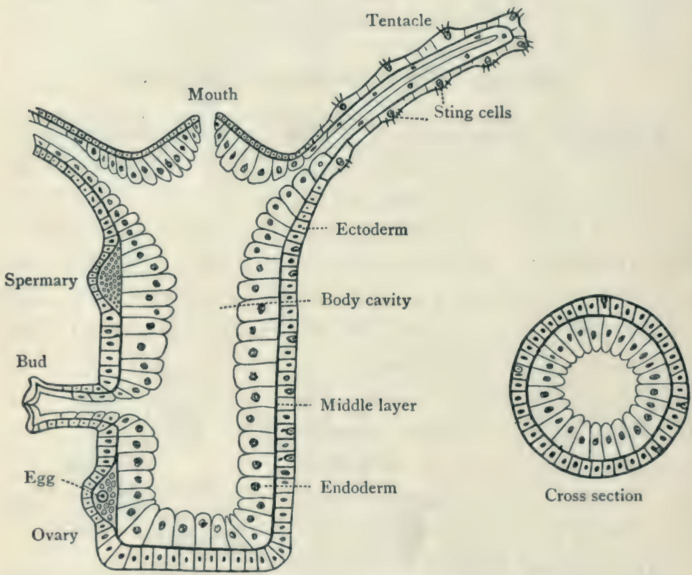


FIG. 180. HYDRA, LONGITUDINAL SECTION.

tions are called muscle processes and are the chief agents in shortening and moving the body. Between the narrowed bases of the larger ectoderm cells are smaller cells, which are supposed to be sensitive, and may perhaps be properly called nerve cells.

Stinging Cells. — Among the cells of the ectoderm, both of the body and of the tentacles, are peculiar bodies called

thread capsules, stinging cells, or *nematocysts.* These are elliptical, and before being disturbed have a fine thread coiled within. When the hydra is irritated, the nematocysts are discharged and the threads are suddenly darted out. At the base of each thread, close to the capsule, are a few fine barbs, and it is supposed that a

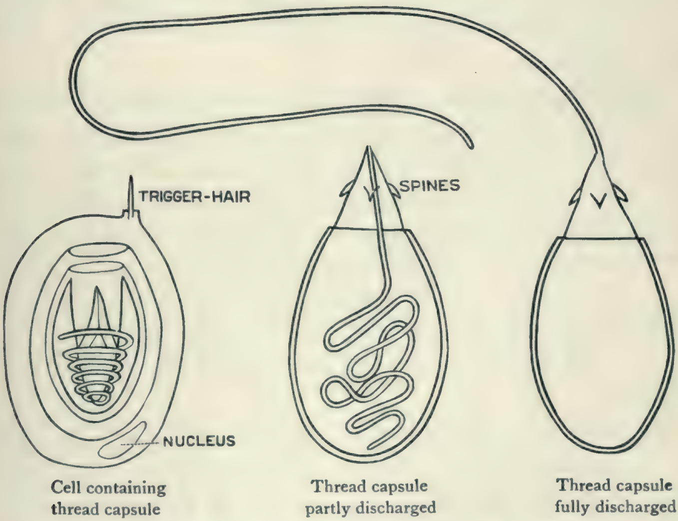


FIG. 181. STINGING CELLS OF HYDRA, HIGHLY MAGNIFIED.

poisonous substance is contained within the capsule. At any rate, the result of coming in contact with this sort of apparatus is a stinging sensation, like that caused by nettles, but, of course, the hydra is so small that it does not produce much effect except on very small animals. But let a small crustacean, such as a water flea, swim against a hydra's tentacle, and it is usually paralyzed at once. Then the tentacles draw the victim to the mouth and it is swallowed.

The Endoderm. — The cells of the endoderm are larger than those of the ectoderm. They are also less uniform in size. They are darker colored, sometimes containing brown coloring matter. The green hydra contains chlorophyll. The endoderm cells often exhibit amœboid movements, and frequently show food particles and large contractile vacuoles, such as noticed in amœba. Projecting from these cells into the cavity are sometimes found large flagella.

Digestion in Hydra. — When food is taken into the central cavity it is supposed to be partly digested here, this often being called the digestive cavity. But, at any rate, particles not completely digested are taken into the endoderm cells, where no doubt digestion takes place; and from the material digested by the endoderm cells the ectoderm gets its nourishment. We here see a division of labor, the outer layer producing the motion, obtaining the food, and protecting the whole, while the inner cells do the work of digestion.

Locomotion. — While the hydra is pretty firmly attached by means of a sticky substance secreted by the cells of the base, it can let go and move away. It sometimes bends over, attaches itself by the tentacles, and then lets go at the base and pulls the base up close to the place where the tentacles are fastened, and by repeating this action crawls along like a "measuring worm." Or it may bend over, attach itself by the tentacles, let go at the base, and turn the base clear over, thus turning a complete somersault, though slowly, instead of with a spring. Sometimes, also, it appears to crawl slowly by means of the tentacles alone. But hydra is not a great traveler, preferring to wait for something to turn up, rather than hunt for food. We see how well fitted it is for a sedentary life, for with the long,

outstretched tentacles, with their many stinging cells, it has a trap continually set for the unwary small swimmers that abound in such places as the hydra inhabits.

Recovery after Mutilation. — One very remarkable fact about hydra is its ability to live and grow after injury. If cut into several pieces, each grows into a complete hydra.

Multiplication by Budding. — Hydra multiplies by budding. A small part of the wall bulges out and forms a cylindric branch, with a double wall continued from the two layers of the body, and the hollow of the branch is continuous with that of the body (see Figs. 179 and 180). After a while, a circle of tentacles is formed at the end of the branch, and an opening appears at the end for a mouth. Finally the base of the branch is constricted and the branch separates and is an independent hydra.

Multiplication by Eggs. — Among the cells of the ectoderm, we noticed that certain cells are smaller and lie deeper than the others. Some of these cells develop into egg cells, or eggs. They are covered by the outer cells, but make a marked bulging. This is the ovary (from *ova*, eggs) and is usually found at about one third of the length from the foot of the hydra (see Fig. 180). A somewhat similar growth occurs near the tentacles, but the contained cells are different. Instead of spherical cells like the egg cells, here are produced cells resembling a miniature tadpole, with an oval head and a vibrating tail. These are the *sperm cells*, or *sperms*, and the enlargement in which they are developed is called a *spermary*.

CLASS I. — HYDROZOA.

Hydroids. — Most of the members of this class are called hydroids, and, as the name implies, they are hydralike.

But instead of being simple most of them are compound, or, as it is more commonly expressed, they live in colonies. We have seen that hydra multiplies by budding. Imagine a hydra in which the budding continues indefinitely, the new individuals remaining connected with the parent, and

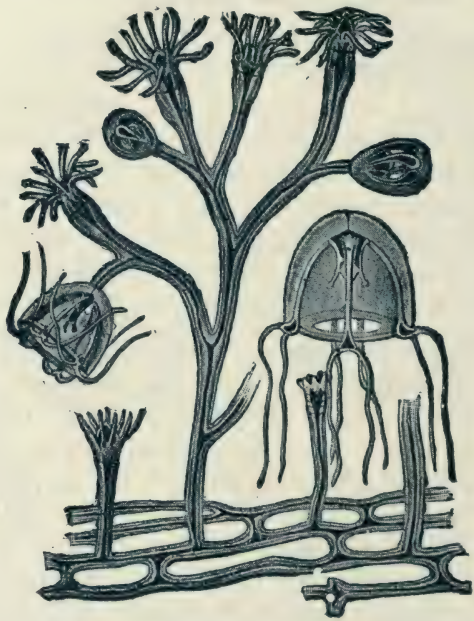


FIG. 182. A HYDROID.
After Allman. — From Kingsley's *Zoölogy*.

you have the hydroid colony. The relation between these members of the colony is more than a mere mechanical connection, for the internal cavity is continuous through the colony, so that whatever one individual takes as food may serve to nourish any one or all the other members of the community.

The idea of community life is well carried out in that there is a well-marked division of labor among the members. Some, called nutritive individuals, devote themselves to the work of obtaining and preparing food for the whole; some develop the stinging cells and protect the others; while still others are specialized for the work of reproduction, and depend on other members for nourishment and protection.

General Appearance of Hydroids. — Most of the hydroids are plantlike in appearance, hence are often called zoöphytes. Some resemble tufts of moss, others are simply branched and trailing like the ground pine. They vary greatly in color, from white to dark brown, while some are of a beautiful pink. A form that will serve well for example is whitish or brownish, and forms a downy or furry coating on the wooden piles of wharves, piers, etc. Many threads creep along the surface, while others rise at right angles to the surface and end in budlike swellings. Examined more closely, these terminal enlargements are found to be bell-shaped. These are the individuals borne on the connecting and supporting stalks. The unit, or zooid, as it is called, is very much like a hydra. The body is hollow, with a circle of arms surrounding the mouth, which is at the free end. It is unlike the hydra in at least three respects. First, the base, instead of being closed, opens into the supporting tube, and this is in communication with all the other zooids of the colony. Second, the tentacles are solid instead of hollow; but they are like the tentacles of the hydra in being flexible and provided with stinging cells that serve for securing food. Third, the mouth is distinctly raised above the bases of the tentacles, and is capable of closing into a cone-shaped mass, the hypostome, or opening into a bell-shaped entrance.

A Tubularian Hydroid. — The general appearance of a zooid of a tubularian hydroid may be seen from Fig. 182. The body is hydralike, but with a prolonged mouth. There are two layers of the body, the ectoderm and the endoderm. The ectoderm of the tentacles is provided with nettle cells.

Structure of the Stem. — The structure of the common stem is similar to that of the zooid. The outer covering of chitin is called the perisarc, while the soft tube within, consisting of ectoderm and endoderm, is called the cenosarc. The endoderm cells have flagella.

Action of a Live Zooid. — The live zooid captures small animals by stinging them as does the hydra. It uses the tentacles to draw them into the mouth. After the food is softened and reduced to a liquid, it is circulated by the vibrations of the flagella of the cells of the endoderm. The nettle cells serve for protection as well as in securing food. When the zooid is disturbed, it withdraws into the protecting cup, or hydrotheca, and may thus remain for some time.

Development of a Zooid — Budding. — The colony increases in extent by budding. A bud forms on the side of a main stem. The bud consists of the same layers as the stem, namely, the perisarc and cenosarc. The bud swells into a knob, the cavity of the main stem extending into it, and the nutritive liquid circulates in the bud. After a time the perisarc ruptures at the end and expands into the cup, the cenosarc forms a mouth at the end, tentacles develop around the mouth, and a new zooid is complete.

How a New Colony is formed — Medusa Buds. — By a continuation of the process just described the colony is increased in extent, but no new colony is formed, for none

of these parts separate from the colony. But certain buds differ from the above. Usually near the base of the colony are to be found longer buds which develop differently. They become long and club-shaped. The soft cenosarc, blastostyle, develops circular side buds, called medusa buds, which finally become detached and swim away, passing out of a hole which is formed at the end of the gonotheca, as the perisarc is here called.

Medusæ. — The medusa bud when developed becomes an umbrella-shaped body, and is called a medusa, or often a hydromedusa. It is, in fact, a small kind of jellyfish. The outside of the umbrella is called the exumbrella and the inside the subumbrella. Hanging from the center of the subumbrella surface is a short handle, the manubrium. It is hollow, and the opening at its end is the mouth. The cavity extends up through the handle, and continues as four radiating tubes to the margin of the umbrella. These four radiating tubes, or canals, are connected by a circular canal, running around near the margin. Food is taken in at the mouth, digested, and circulated through this system of canals. From the margin of the umbrella a short fold or shelf extends inward horizontally, and is called the veil (velum). Around the margin are numerous tentacles, and on the margin certain spots supposed to be organs of a sense of direction. Some medusæ have around the margin of the umbrella a series of black spots, which are rudimentary eyes. The umbrella has the power of expanding and contracting, and by this means the medusa swims. Sometimes it turns inside out.

How a Medusa Multiplies. — Suspended from the subumbrella surface, close to the four radial canals, are four spherical bodies. These are the gonads. In one individual the gonads produce eggs (ova), and in another

individual they produce sperms. The gonads set free their contents in the water, and the eggs are fertilized by the sperms. After fertilization, the egg develops first into a simple hydralike polyp, and later, by budding, into a branched hydroid like the form that produced the medusa.

Fig. 183. Portuguese Man-of-war.

Alternation of Generations. — Thus we see that these hydroids have two forms, and neither one is complete. The hydroid form can spread as a colony, but it can form no new colony. But by means of the medusæ, which are free-swimming, it forms new colonies, which may be at a distance from the original colony. This peculiar process of development, hydroids giving off medusæ, and medusæ, in turn, producing eggs which develop into hydroids, is known as "alternation of generations." It is found in some other lower animals, and among the Arthropods.

Other Forms of Hydrozoa. — The great majority of Hydrozoa have an alternation of generations as described. But there are others in which there is only a medusa form, no polyp form appearing, the eggs produced by the medusa developing directly into a medusa form. In others the medusa buds are produced, but are not set free. While remaining attached, they produce and set free the eggs

and sperms, which develop into polyp form. The siphonophores are in colonies, but, instead of being fixed, are free. Some swim by means of bell-shaped zooids, resembling a cluster of medusæ, while other zooids in the group devote themselves to nutrition, and others to the work of protection. In other kinds of siphonophores there is a bladderlike float, and locomotion depends upon the wind and current. The Portuguese man-of-war is an example. All forms are well provided with stinging cells, and one who handles them carelessly finds that this whole branch may well be designated "the sea nettles."

CLASS II. — THE SCYPHOZOA.

Jellyfishes. — This class is mostly made up of the larger jellyfishes. One of the most common on the New England coast is the common white jellyfish, known as Aurelia. It is saucer-shaped and frequently is a foot or more in diameter. It is gelatinous and semitransparent. In the center of the subumbrella is a short stalk, or manubrium. At the end of this is the square mouth, from the corners of which extend four delicate processes, the oral arms. The short gullet leads from the mouth to a roomy stomach, whose four gastric pouches extend halfway to the margin. There are many fine radiating canals and a small, circular marginal canal. On the floor of each gastric pouch is a brightly colored gonad, whose contents, eggs or sperms, are discharged into the stomach and pass out through the mouth. Along the inner border of each gonad is a row of delicate gastric filaments, well supplied with stinging cells, whose function is to paralyze the animals taken in as food. The margin has a fine fringe of tentacles. Evenly distributed on the margin are eight peculiar sense organs.

Development of the Scyphozoa. — The egg, after being fertilized, divides into many cells. These finally arrange themselves into a two-layered sac. This becomes cylindrical and attaches itself by one end. The other end opens to form a mouth, around which tentacles develop,

FIG. 184. JELLYFISH.

The four long projections are the oral (mouth) appendages. The slender hanging projections are the marginal tentacles.

thus forming a hydralike or polyp form. This elongates and becomes constricted transversely so that it resembles a pile of saucers, each of which is scalloped. These saucer-shaped parts become detached in order from the

top, each, except the first, forming a jellyfish. The surface that was uppermost becomes the subumbrella.

Other Jellyfishes. — Most of the jellyfishes are essentially similar to Aurelia, though they differ considerably in their shape, some being conical instead of saucer-shaped. They often are seen in great schools, swimming lazily by gently opening and closing the umbrella, or floating at the surface; or they may sink out of sight at will. They are mostly marine, and most are free-swimming, though a few are permanently or temporarily attached by the exumbrella surface. They are all carnivorous, feeding largely on crustacea. Most of them are very beautiful, being like cut glass, or brightly colored, many being beautifully phosphorescent. The great blue jellyfish of the New England coast sometimes is seven feet in diameter with tentacles a hundred feet long. Smaller specimens of this sort, when seen by transmitted light, as when in an aquarium, resemble immense amethysts.

CLASS III. — ACTINOZOA.

Sea Anemones. — To this class belong the sea anemones and most of the coral polyps. The common sea anemone is hydralike, that is, it is cylindric, attached by the base. The tentacles are numerous and are borne on a disk surrounding the mouth at the free end. The mouth is an elongated slit. The internal structure differs considerably from that of the hydra. In the first place, the mouth does not open directly into a simple body cavity, but is continued as a tubular gullet, which extends halfway down the body. A series of radiating partitions run the whole length of the body, extending from the outside of the gullet to the body wall. Below the lower end of the

gullet the free inner edges of these partitions, the mesenteries, may be seen.

Digestion in the Sea Anemone.—Small animals, such as crustaceans, mollusks, and fishes, which come in contact with the tentacles, are partially paralyzed. They are then drawn into the mouth and passed through the gullet into the digestive cavity below, which may perhaps be called

FIG. 185. SEA ANEMONE.
After Emerton. — From Kingsley's *Zoölogy*.

the stomach. On the edges of the mesenteries below the gullet are many threadlike projections, called the mesenterial filaments. These filaments are richly provided with nettle cells, which complete the killing of the prey. The filaments are also furnished with gland cells, which supply the liquid for digesting the food. The liquefied food material may pass up into all the spaces between the mesen-

teries, or intermesenteric spaces, as they are called. There are holes through the mesenteries near the top, so these chambers may communicate with one another. Between the mesenteries are ridges, extending inward from the outer wall, but not reaching the gullet. These are incomplete or secondary mesenteries.

Change of Form of the Sea Anemone. — When undisturbed the animal is cylindrical, sometimes long, sometimes broad, so that many of them resemble the flowers of the chrysanthemum, daisy, anemone, and sunflower. They well deserve the name, for many of them are beautifully colored. The tentacles are often banded with variegated colors. It is hard for one who has lived all his life inland to realize that such brilliantly colored, flowerlike forms are actually animals and not plants. But disturb one of these flowerlike animals and it shows its real nature. It at once begins to shorten, to withdraw its tentacles, and shrink into a rounded mass lying close to its attachment. The mesenteries are well supplied with longitudinal muscles, whose shortening draws the body down close. Near the margin of the disk are strong circular muscles which shorten and shut in the free end, over the retracted tentacles, like a bag with a draw-string, so that all that appears resembles an old felt hat, with, perhaps, a little indication of a hole at the apex. After the disturbance ceases the sea anemone may gradually expand again.

Development of the Sea Anemone. — Sea anemones lay eggs, which are developed in the mesenteries near their free edges. The later development resembles that of the jellyfishes, but there is no alternation of generations.

General Characteristics of Sea Anemones. — Sea anemones are all marine. They are all single, that is, they do not form colonies. They have no true skeleton. Some

sea anemones attach themselves to the shells inhabited by hermit crabs. They thus get transportation, and are more secure of getting food. In return they protect the crab, for few animals care to eat so tough and nettling an animal as a sea anemone.

Coral Polyps. — The coral polyps are essentially like the sea anemone in their structure. But, unlike the sea anemones, they are almost always in colonies. They are unlike the sea anemone, too, in secreting carbonate of lime at the base. The single coral makes a cup or circular

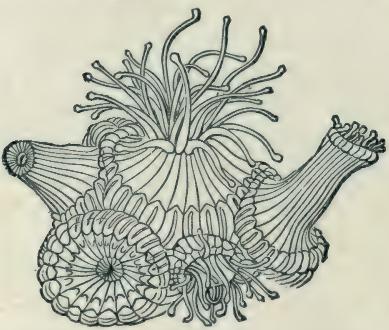


FIG. 186. A CLUSTER OF NEW ENGLAND CORAL POLYPS.
They secrete but little coral.

wall, with radiating partitions, these radiating partitions alternating with the mesenteries. In the colonies these individual cups fuse more or less together, making immense masses of coral.

Kinds of Coral Polyps. — Coral polyps are usually classed in two groups, according to the number of tentacles. In the sea anemone the tentacles are some multiple of six. Some authors call these Hexacoralla. To this group, besides the sea anemone, belong all the true corals which produce coral reefs and islands. As is well

known, they cannot build coral in cold water, being limited to about the temperature of 60° F. The other group have the tentacles on the plan of eight, and are sometimes therefore called Octocoralla. They make little coral, but form whiplike and fanlike colonies, the sea

FIG. 187. RED CORAL POLYPS.

fans, and sea pens, or sea whips. These have a horny core with loose limy material on the outside. To this group belongs the well-known red coral of the Mediterranean. The polyps of many of the corals are exceedingly brilliant.

GENERAL CHARACTERISTICS OF CŒLENTERATA.

1. There is no digestive tube separate from the body cavity.

2. Stinging cells are almost always present.

3. The body is usually radially symmetrical, but in some there are traces of bilateral symmetry.

4. In addition to producing eggs, many multiply by budding, which often results in (5),

5. Colonies, often showing marked division of labor among the differentiated individuals, or zooids.

6. The body consists of three layers: an ectoderm, and endoderm, and a middle, supporting layer, called the mesoglea.

7. The cœlenterates are mostly marine.

CLASSIFICATION OF CŒLENTERATA.

Class 1. Hydrozoa; examples, hydra and the hydroids.

Class 2. Scyphozoa; examples, most of the large jellyfishes.

Class 3. Actinozoa; examples, the sea anemones and most stony corals.

Class 4. Ctenophora, the "comb jellies."

CHAPTER XXI.

BRANCH ECHINODERMATA.

THE echinoderms include the starfishes, brittle stars, sea urchins, sea lilies, feather stars, and sea cucumbers, all exclusively marine.

CLASS I. — ASTEROIDEA.

Example. — The Common Starfish.

Occurrence. — The common starfish is found all along the Atlantic coast from Labrador to Florida. It is more abundant in the shallower water, especially on the oyster beds. Other kinds of starfishes are found deeper.

General Appearance. — The common starfish is a five-rayed star. The central body is called the disk and the arms are the rays. In the center of the more flattened surface is the mouth; hence this surface is called the "oral" surface in distinction from the opposite "aboral" surface, which is more convex.

The Skeleton. — One of the noticeable features of the starfish is its roughness. This is due to the limy skeleton, which consists of many small pieces (ossicles) of calcareous material loosely and, in the main, irregularly joined together by more or less muscular tissue, so that the starfish can turn or twist the rays about to a considerable extent. The skeleton is embedded in the tough body wall, which is more or less ciliated, externally and internally. Many of the ossicles bear rigid projecting spines, while on

the oral surface, especially along the borders of the grooves on the oral surfaces of the rays, are movable spines attached to the ossicles of the body wall.

On the aboral surface are many small pinchers, consisting of a short stalk bearing two calcareous blades. The

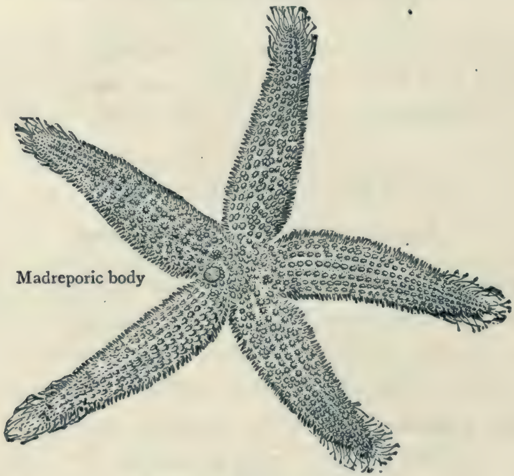


FIG. 188. COMMON STARFISH.

stalks are flexible, and the blades of the pinchers may be seen opening and closing. It is thought they are for the purpose of keeping the body clean by picking up and removing small particles. These pinchers are called pedicellariæ.

The Water Tube System. — Before we can understand how the starfish locomotes we must get an idea of the water tube system, or water vascular system, as it is usually called. In the first place, an examination of a live starfish will show the rows of soft, flexible, cylindric tube feet in the grooves in the rays. By watching the live animal it

will be seen that these tube feet are retracted, extended, and variously moved about. For protection the feet can be withdrawn into the groove. But commonly the feet are applied to the surface on which the starfish is creeping. Each tube foot is a hollow cylinder, containing water, and is connected by a slender tube, passing between the ossicles, with a water bulb in the cavity of the ray. Both the foot and the bulb are muscular, so when the bulb contracts it forces more water into the foot and

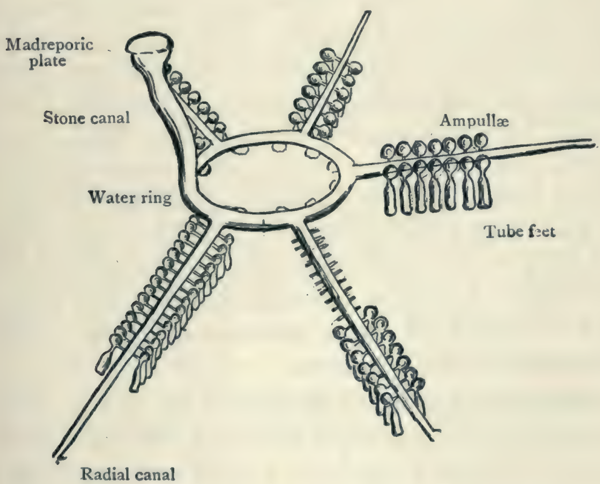


FIG. 189. WATER TUBE SYSTEM OF STARFISH.

extends it; and when the foot shortens it can send the water back into the bulb. Around the mouth is a circular water tube, which sends a tube along each ray; and side branches from these radiating tubes supply the tube feet. On the outside of the aboral surface, between the bases of two of the rays, there is a wartlike body. This is the madreporic plate. It is perforated. Water enters it and

passes down through a *madreporic canal* or *stone canal* (made of the same material as the skeleton), and this stone canal empties into the circular water tube around the mouth. Thus water, filtered through the madreporic plate, is supplied to the whole water tube system. There is also a series of water bulbs opening into the circular water ring; these are the Polian vesicles.

How the Starfish Crawls. — When the starfish wishes to crawl, it distends the tube feet by the action of the water bulbs (or water sacs, called *ampullæ*) along the inside of the rays. The flattened disklike ends of the feet are closely applied to the surface on which it is crawling. Then the center of the disk is somewhat retracted, making a sort of "sucker," by which the foot holds firmly. When many feet are thus holding there is considerable power, and when the feet are now shortened the body as a whole is pulled along. The starfish can climb vertical walls or even cling to the under side of a horizontal surface. And so strongly can it hold that sometimes, when the collector tries to pull it away he simply tears the starfish in two. The starfish can crawl with any ray foremost.

The Digestive System of the Starfish. — The mouth opens into a large stomach which fills nearly all the space in the central body, and has, in addition, a large lobe extending a short distance into each ray. The stomach is thin-walled and very extensible. This wide part of the stomach is called the cardiac portion. The stomach narrows above, and again widens to form the pyloric portion. Into this portion is poured the secretion of ten digestive glands, a pair in each ray. The ducts of the two glands in each ray unite, so there are five ducts entering the pyloric stomach. These glands are like long bunches of small grapes. The glands are held in place by thin folds of the

lining membrane of the ray, and are called mesenteries. From the pyloric stomach a slender intestine extends up to the aboral wall, a little to one side of the center. Its opening is hard to find and in some starfishes is entirely obliterated. There are no jaws nor any teeth in the starfish.

The Starfish's Food and Mode of Eating. — Starfishes feed chiefly on mollusks, especially on oysters and mussels. The starfish arches the body over the oyster, and then turns its stomach inside out and around the soft body of the oyster, and, after digesting it, withdraws the stomach again. This seems an odd way of eating, but certainly it is an economical way, for the starfish takes only what it can digest and absorb.

Damage done to Oysters. — The starfish is a very voracious animal, and the injury done by it to the oyster industry is very great. The oystermen have learned that they must make effort to keep the oyster beds clear of starfishes.

How Starfishes recover after Mutilation. — A starfish torn in two will grow, and may make two complete starfishes. The oystermen know that it will make a bad matter worse to tear the plunderer into pieces and throw them back into the water. Experiments show very great power of recovery after mutilation. Frequently one finds starfishes with one ray missing, or even two or three. Occasionally the collector finds a specimen with but one fully developed ray, the other four having been lost. Four new rays may, perhaps, be started, which in course of time will grow to full size.

The Body Cavity. — The starfish is a decided advance on the cœlenterate type of structure in having a distinct body cavity, separate from the digestive tube.

Circulation. — There is no well-developed circulatory system, such as we find in the higher animals. There are blood corpuscles in the liquid contained in the general body cavity. This liquid pervades all parts, and is set in motion by the cilia of the lining membrane, and by the general movements of the stomach and the bending of the rays; these movements seem to suffice to circulate the contained liquid, which probably directly receives the absorbed products of digestion.

Respiration in Starfishes. — There is no very complete system of respiration in starfishes. In fact, no such system is needed, for the whole body, inside and out, is constantly bathed in sea water. Still, it is thought by many authors that the tube feet are the chief agents in absorbing oxygen from the water and giving off the waste. There are also many holes through the aboral wall, from which extend slender projections of the thin, soft lining membrane of the body cavity. These are now supposed to be gills.

The Nervous System and Senses. — The nervous system is near the surface, and can be seen without dissection. Around the mouth is a five-angled nerve ring, which gives off a radial nerve along each ray. It may readily be seen by separating the tube feet along the middle line.

At the extreme end of each ray is an eye spot, which shows as a distinct red spot in a fresh specimen of the common starfish. In alcoholic specimens it is hard to see.

Close to the eye is what appears to be a tube foot, but without the disk at the end. This is called a tentacle, and is now believed to be an organ of smell. The sense of smell seems to be a much better guide than sight in bringing the starfish to its food. There is undoubtedly some sensitiveness to touch, but of this and any other senses little is known.

Development of the Starfish. — The female has a pair of ovaries at the base of each ray. They are like slender bunches of tiny grapes. The eggs pass out of minute pores in the angles between the bases of the rays. In the males the spermaries occupy a similar position and resemble the ovaries in form, but are lighter colored, usually white. The young starfish goes through a remarkable transformation, the young no more resembling the adult than in the case of many insects with which we are familiar. The most striking fact is that the young is very distinctly bilaterally symmetrical, showing no traces of radial symmetry.

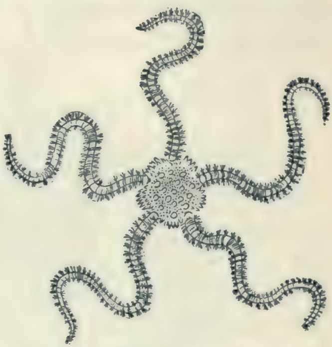


FIG. 190. BRITTLE STAR; SAND STAR.

Other Forms of Starfishes. — Most starfishes are five-rayed, but in some the rays are so short that the whole animal is a pentagon, the rays hardly extending beyond the disk. Some are brilliant, exhibiting beautifully complementary colors of purple and orange. The number of rays may be as many as twenty. A Pacific starfish sometimes becomes two feet in diameter.

CLASS II. — OPHIUROIDEA.

The Brittle Stars. — The ophiuroids are represented by the brittle stars. Their general form is similar to that of the starfishes. But the central disk is more distinct and the arms relatively slender. The arms are more flexible and the brittle star locomotes by active lateral movements of the arms, making rapid progress compared to a starfish.

The arms are not hollow as in the starfish, there is no ambulacral groove and the tube feet project on the side instead of on the oral surface. On account of the tapering arms, with their active wriggling movements, the brittle stars are sometimes called serpent stars. They are also called sand stars. In some ophiuroids the arms are branched as in the common basket star, whose arms are many times branched, and become so inrolled as to give the name basket-fish.

CLASS III. — ECHINOIDEA.

Occurrence. — Sea urchins are found along the Atlantic coast from low-water mark to fifty fathoms, being more common among rocks. They are also found clinging to the piles of wharves. The northern form is greenish, with slender spines, somewhat resembling a chestnut bur. The more southern form is of a dark color, with fewer and stouter spines.

General Form of a Sea Urchin. — The common sea urchin is apple-shaped, the mouth being where the stem of an apple is, and the anus at the opposite end, or pole, as the ends are termed. Running from the mouth to the anus are meridians, marked especially by the five double rows of tube feet, which, when fully extended, are long and slender, reaching beyond the tips of the longest spines. For some considerable space around the mouth is a leathery membrane, the peristome, where the skeleton is undeveloped.

The Skeleton. — As in the starfish, the leathery body wall abounds in limy plates, or ossicles; but instead of being loosely attached to each other, as in the starfish, they are, in the sea urchin, firmly cemented together, constituting a rigid shell. These shells are sometimes sold under the

name of sea eggs. In a cleaned shell, or corona, as it is sometimes called, there are found ten double rows of calcareous plates, making twenty in all. Every alternate double row is closely perforated for the passage of the tube feet. These perforated plates are called the ambu-

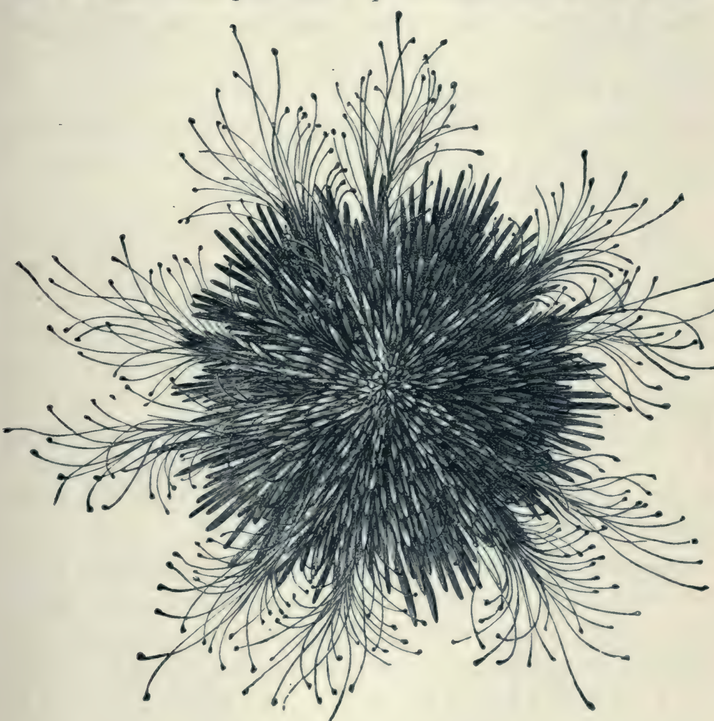


FIG. 191. SEA URCHIN.

The heavy projections are the spines; the long, slender ones are the tube feet.

lacral plates. Both the ambulacral and the interambulacral plates bear rounded elevations, on which the spines were borne. Each spine has a hollow in its base, which fits over an elevation on the shell, making a ball-and-socket

joint, and is capable of a limited motion in any direction by means of muscles attached around the base. Between the spines are the pincherlike pedicellariæ, as in the starfish, only here they have three blades instead of two.

The Water Tube System. — The sea urchin has a water tube or water vascular system essentially like that of the starfish. There is a water ring around the gullet, with radiating tubes between the rows of feet along the ambulacral rows. Inside the shell are water bulbs, or ampullæ, as in the starfish, and the mechanism for the operation of these parts is as described for the starfish.

How the Sea Urchin Locomotes. — The injected feet are extended and attached by means of the suckerlike action at the end of each foot. Then the muscular shortening of the feet pulls the sea urchin along. This means of progression is also aided considerably by the movements of the spines. The sea urchin can climb perpendicular surfaces. When placed on the aboral surface, it can turn over, though it is a very slow process. Sea urchins are sometimes found in deep holes in rocks, and it is believed that they have gradually made the holes.

Digestive System of the Sea Urchin. — Projecting from the mouth are usually to be seen five hard, white teeth. These teeth are movable, not being set in sockets, but held in a very complicated apparatus, somewhat like a five-angled top, known as Aristotle's lantern. The whole apparatus is under muscular control. Through the center of the whole runs the gullet. Above the tooth apparatus the intestine runs around the body wall, then reverses, making in all about two and a half turns around the body wall. It then extends up to the apex, where it ends in the anus, guarded usually by four calcareous plates. It is held in place by a thin membrane, the mesentery.

The food is varied. Sea urchins sometimes eat sea weeds. At other times they are found eating fish, etc., that have been thrown out as refuse by the fishermen. Sea urchins are of no special economic importance, neither being of any use nor doing any damage.

Respiration in the Sea Urchin. — Around the mouth, on the leathery membrane known as the peristome, are some specially modified tube feet which are supposed to act as gills. But, as in the starfish, the whole body, inside and outside, is so thoroughly bathed in water that there hardly seems a need of any special organs of respiration.

The Nervous System of the Sea Urchin. — This, too, is very similar to what we have seen in the starfish. There is a nerve ring around the gullet, from which a radial nerve passes along the ambulacral line, between the rows of tube feet, just within the body wall.

At the end of the series of ambulacral plates is a single plate, known as the *ocular plate*, on which is an eye, at the very tip of each radial nerve.

There are also, over the surface of the body, a number of small spherical bodies, borne on movable stalks. These bodies (spheridia) have ganglion cells in them, and are regarded as sense organs.

Development of the Sea Urchin. — The ovaries are situated in the aboral part of the body cavity and are placed in the interambulacral spaces. A duct from each ovary opens through a plate at the end of the series of interambulacral plates. These plates with the genital pores are called the "genital plates," and alternate with the ocular plates that have been described as occurring at the apex of the series of ambulacral plates. In the male the spermaries occupy a similar position, and have similar genital pores. In the Southern sea urchin the ovaries are red

from the color of the contained eggs, while the spermaries are white. The ovaries and spermaries are similar in form, resembling small bunches of grapes; and if it were not for the difference in color, it would require microscopic examination to distinguish the two sexes. Both the eggs and sperms are discharged into the water. The sperms are microscopic, tadpole-like bodies, swimming actively by the vibration of their tails. If the sperms do not gain access to the eggs, the eggs do not develop, but soon die. But usually the sperms surround the eggs, there being, ordinarily, many sperms to each egg. One sperm gains entrance to an egg, at least the head fusing with part of the egg. The egg is now said to be fertilized.

After fertilization, the egg mass contracts, leaving a clear space around it inside the outer coat, or cell wall. Soon the egg mass within divides into two equal parts, each of these halves again divides into two, the four then become eight, sixteen, thirty-two, and so on until the number can no longer be counted and the egg looks like a spherical mulberry. This process of division is known as segmentation. The berrylike mass now becomes hollow, consisting of a single layer of cells. Next one side is pushed in like a rubber ball with one side punched in; it now has a wall made of two layers of cells. On the outside are little hairlike projections of the cells, called cilia, which by their vibrations propel the body through the water. A set of needlelike rods develop within the embryo, which soon make a skeleton, shaped somewhat like a common chair. This skeleton has a covering of soft tissue, and the projections, which correspond to the legs of the chair, are covered with strong cilia for locomotion. The digestive tube has at first but one opening, that made by the doubling in of the outer wall, as above mentioned,

and the cavity of this depression forms the digestive cavity. The mouth is formed later by a new opening made through the outer wall into the first cavity, and the original opening becomes the anus. So far the young sea urchin is very unlike the adult; but after a time this larva begins to transform into the real sea urchin, and soon the little sea urchins, about the size of pins' heads, are found crawling up the sides of the glass vessels in which they are kept. It should be noted that the larval sea urchin is bilaterally symmetrical, whereas the adult is, apparently at least, radially symmetrical.

Other Forms of Echinoids. — In addition to the common apple-shaped sea urchins, we find very greatly flattened forms, such as the sand cake, or sand dollar, also called cake urchin. The mouth is central, but the anus is at one edge. Slightly different is the key-hole urchin, with narrow openings through the shell (not communicating with the body cavity). There are some elongated urchins, showing rather marked bilateral symmetry.

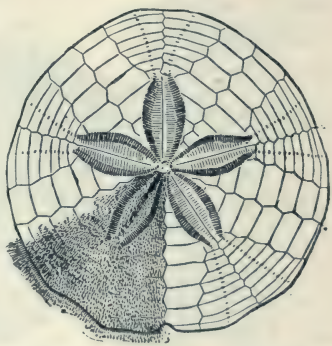


FIG. 192. SAND DOLLAR; CAKE URCHIN.

The spines are removed from most of the surface.

CLASS IV. — HOLOTHUROIDEA.

Sea Cucumbers. — Our larger holothurians are cucumber-shaped, hence the common name, sea cucumber. The mouth is at one end and the anus at the other. Around the mouth is a circle of tentacles, with which food is taken. Along the sides, usually in five distinct rows, are

the tube feet. Sometimes the radial symmetry is more or less altered, for some of these forms so habitually rest, or creep, on one side that they are said to have a dorsal and a ventral surface. A sea cucumber may be compared to a sea urchin that has been drawn out in the direction of the poles — that is, from mouth to anus — and further to have lost most of the ossicles in the body wall so that it is now flexible instead of being rigid. There are many

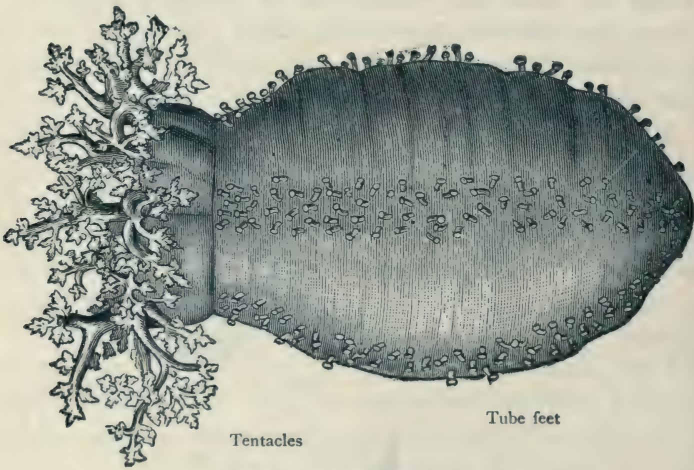


FIG. 193. SEA CUCUMBER.

microscopic spicules in the integument that give it roughness and sometimes some degree of stiffness. Various forms of holothurians are found along the Atlantic coast. Some of the holothurians are so extremely elongated that they are frequently mistaken for worms. Among the Chinese and other West Pacific peoples, sea cucumbers, under the name trepang, are variously prepared for food. They are used principally for soups, and are considered a great delicacy.

CLASS V.—THE CRINOIDEA.

Sea Lilies. — The stalked crinoids are borne on a slender stalk of calcareous disks, so connected as to allow of considerable freedom of motion. The body is flowerlike, with branching arms surrounding the central mouth. Most of the living crinoids are found in deep seas, and are known as the sea lilies. In shallow water is found a form that is stalked in its earlier life, but later the body, with its feathery arms, is set free and swims away by the motions of the arms. These are known as the feather stars.

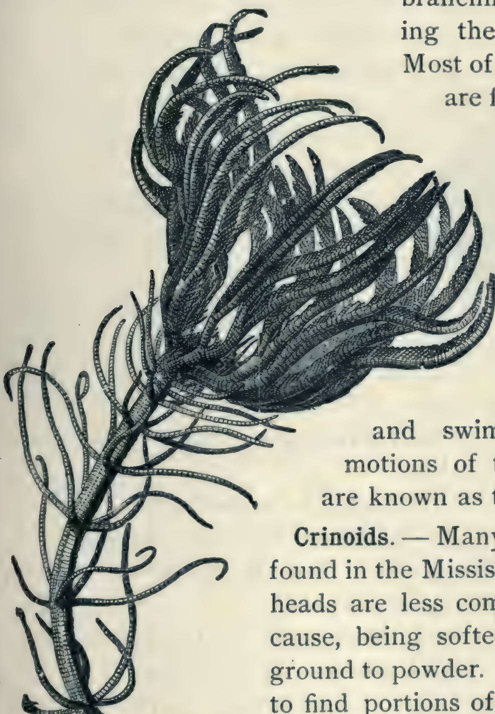


FIG. 194. A CRINOID, OR FEATHER STAR.
From Kellogg's *Zoölogy*.

Crinoids. — Many fossil crinoids are found in the Mississippi Valley. The heads are less common, perhaps because, being softer, they have been ground to powder. But it is common to find portions of the stems, which look like a series of buttons piled one upon another, with a more or less evident hole running through the center. These appear to have been so abundant in the seas of former ages that they have formed whole strata of limestone rock.

GENERAL CHARACTERISTICS OF ECHINODERMATA.

1. The body and its various organs are radially arranged. But many show more or less bilateral symmetry.

2. In their development they all undergo a marked metamorphosis, the young being bilaterally symmetrical, and only in a later stage acquiring the radiate arrangement.

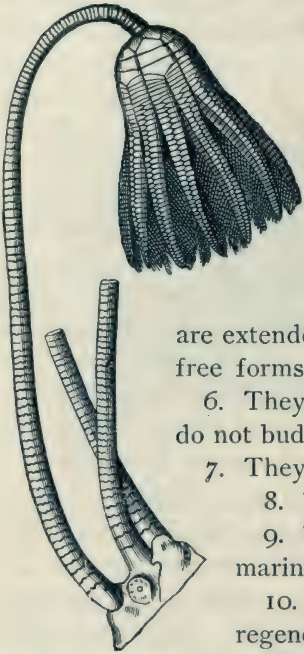


FIG. 195. STONE LILY (CRINOID).
From Packard's *Zoölogy*.

3. The surface has an exoskeleton of calcareous plates, with movable spines.

4. There is a well-developed digestive tube, distinct from the body cavity.

5. There is a peculiar system of water tubes by which tube feet are extended and locomotion effected in the free forms.

6. They reproduce by means of eggs, and do not bud.

7. They do not occur in colonies.

8. They are all rather sluggish.

9. They are all, without exception, marine.

10. They have remarkable power of regeneration after mutilation.

The echinoderms were formerly classed with the cœlenterates on account of the radial arrangement of the parts of the body; but the echinoderms differ sharply from the cœlenterates in having a digestive tube distinct from the body cavity, and in having a much higher development, as shown in the variety and perfection of their

organs. The echinoderms are a very distinct group, standing apart from all other branches of the animal kingdom.

CLASSES OF ECHINODERMATA.

Class I. Asteroidea — Starfishes.
Class II. Ophiuroidea — Sand Stars and Brittle Stars.
Class III. Echinoidea — Sea Urchins and Cake Urchins.
Class IV. Holothuroidea — Sea Cucumbers, or Sea Slugs.
Class V. Crinoidea — Sea Lilies and Feather Stars.

CHAPTER XXII.

BRANCH PLATYHELMINTHES.

The Flatworms.

[The word "worm" is used in a very loose and indefinite way. In popular language it is applied indiscriminately to the legless earthworm, the insect larva with segmented appendages (caterpillar), and to the elongated mollusk styled the shipworm. All that is required to merit the title is a soft, elongated, bilaterally symmetrical body. This superficial view makes no distinction as to whether the body is segmented or unsegmented, whether appendages are present or absent, whether the form is that of an adult or only in the larval stage, and asks no questions as to internal structure. The old group of "Worms" had no fundamental unity in plan of structure; in fact, they had nothing in common except a general similarity in form. Hence it is natural that an increasing knowledge should break up the old branch "Vermes." In its stead we find what were formerly reckoned as classes of the branch elevated to the rank of branches, as follows: Platyhelminthes, the flatworms; Nemathelminthes, the roundworms; Trochelminthes, the rotifers or Wheel Animalcules; the Molluscoida; and the Annulata, the segmented or ringed worms, such as the earthworm.]

The Platyhelminthes. — As the name indicates, the body is flattened. They are bilaterally symmetrical, and without skeleton or body cavity. There is no system of blood-tubes. The body has three embryonic layers, ectoderm.

mesoderm, and endoderm. Many of them are parasites, and some wholly lack a digestive tube. When present the digestive tube has but one opening, the mouth. They show a tendency to reproduction by self-division, and most of them when cut in two develop two individuals.

The Tapeworm. — Probably the most widely known of the flatworms are the tapeworms. These are parasites in the digestive tube of various vertebrates, including man. As the name indicates, the body is ribbon-shaped, sometimes attaining a length of thirty feet. The body consists of segments, or proglottids, a tapeworm ten feet long having about eight hundred segments. There is no mouth nor digestive tube; none is needed, as the worm lives surrounded by material digested by another animal, and the parasite simply absorbs nourishment through its skin. There is a distinct head, whose chief work is that of attaching the worm to the lining of the intestine; this is secured by a circle of hooks at the end of the head and four sucking disks on the sides. For a short distance from the head the body is unsegmented; then segments are formed by constrictions at intervals; farther on, the segments grow larger.

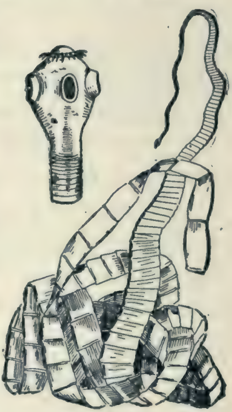


FIG. 196. TAPEWORM (*Tænia solium*).

In upper left-hand corner of figure the head much magnified. After Leuckart. — From Jordan and Kellogg's *Animal Life*.

Development of the Tapeworm. — The hinder segments of the tapeworm contain embryos. These segments drop off and the embryos are set free, passing out with the excrement. They are eaten by another animal, the hog, for instance; in the intestine the embryo bores through the

wall of the intestine into the muscles or other tissues. Here it becomes flask-shaped (bladder worm) and develops a head with hooks and suckers; but in this condition it must remain unless eaten by some other animal. If the flesh be cooked, the bladder worm (cysticercus) will be killed. The danger comes in eating raw or half-raw meat. If taken into the intestine of another animal, it attaches by hooks, or suckers, or both, and the body elongates by the formation of segments as above noted.

Kinds of Tapeworms. — Man is infested by at least three different kinds of tapeworms, — one obtained from pork, another from beef, and a third from fish; but the latter kind is seldom, if ever, found in this country.

Various animals have their own kinds of tapeworms, usually getting them from a certain kind of animal on which they prey; thus the dog has tapeworms which have passed their larval stage in the muscles of the rabbit. The cat gets a tapeworm from the mouse.

The Liver Fluke. — This is another of the flatworms. It is a parasite in the liver of the sheep, living in the larger bile ducts. The eggs develop into embryos which escape with the excrement. Then they pass into the bodies of snails. Here they reach the larval stage. After leaving the snail, they attach themselves to damp grass under water. If eaten by sheep, they become fully developed worms like the adult from whose eggs they developed. In England it was estimated that 3,000,000 sheep were killed by the liver fluke in 1880, and that the average yearly loss is 1,000,000.

FIG. 197. LIVER FLUKE.
A trematode worm.

CLASSES OF PLATYHELMINTHES.

Platyhelminthes.	Class 1.	Trematoda — Liver Fluke.
	Class 2.	Turbellaria — (ciliated).
	Class 3.	Cestoda — Tapeworm.

BRANCH NEMATHELMINTHES.

THE ROUNDWORMS.

The roundworms have long, cylindrical bodies. They are not segmented, but some of them have the appearance of segmentation. Some are parasites in animals and plants, while others live a free life. Most of the roundworms belong to the class Nematoda.

Hair Worms. — These are often found as parasites in grasshoppers and other insects, but later they live free outside. They are by many ignorant people believed to be horsehairs that have "come to life" by soaking in water.

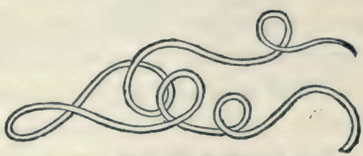


FIG. 198. HAIR WORM.

The Vinegar Eel. — This is another small roundworm which is well known.

Intestinal Worms. — Two forms of roundworms are not uncommon in the human intestine, especially in those of children. The eggs or larvæ have been swallowed with food. The pinworm is well known; it is small and white and usually inhabits the rectum. The other is larger, sometimes somewhat resembling an earthworm in size and general appearance, though lacking the segments. It belongs to the genus Ascaris.

Trichina. — The most dangerous of the parasitic roundworms is Trichina. It is small, not exceeding an eighth

of an inch in length. It is sometimes called the "pork-worm." As is well known, this parasite is obtained by eating raw or partially raw pork, and there is no danger when the flesh is thoroughly cooked. If they gain access to the intestine of the pig, the females bring forth alive a

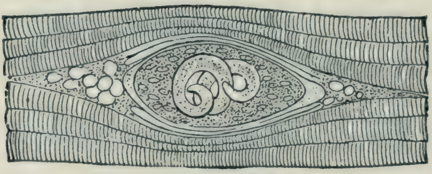


FIG. 199. TRICHINA ENCYSTED IN HUMAN MUSCLE.
Highly magnified. — From Packard's *Zoölogy*.

large number of young. These bore their way outward into the muscles and there inclose themselves in a sac or capsule, where they may remain an indefinite time. If this pork, uncooked, is eaten by man, the capsule is digested and the larvæ are set free. The young soon bore through into the muscles and each worm gets into a muscle cell and coils up in a case or "cyst," which it forms for itself.

The Guinea Worm. — In the East Indies occurs another parasite, the guinea worm. It is sometimes found two feet long, embedded in the connective tissue under the human skin. It is supposed that the eggs or larvæ are introduced in drinking water.

BRANCH TROCHELMINTHES.

THE ROTIFERS.

The Wheel Animalcule. — The word "Rotifer" means wheel bearer, from the two circular disks at the anterior end, around the borders of which are circles of cilia whose

motions resemble the rotation of a wheel. These disks can be retracted when the animal wishes. The common name for one of these animals is the "wheel animalcule." As implied by the term animalcule, the animals are small, usually not exceeding a thirtieth of an inch in length. They occur in fresh water, and are usually to be found when looking over minute water plants under the microscope. They are transparent and are easily examined, all their organs showing without dissection. Though small, they are highly organized, having a complete digestive system, the food being swept to the mouth by the cilia bordering the disks. There is also a nervous system, with one or more eyes.

They can swim by the action of the cilia and they also progress by a looping movement, attaching alternately by

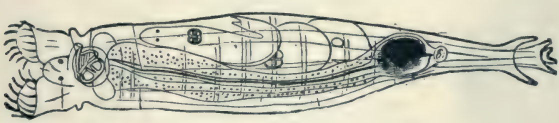


FIG. 200. WHEEL ANIMALCULE (ROTIFER).
From Packard's *Zoölogy*.

the two ends of the body. The posterior part of the body is a segmented "tail" which can be withdrawn like a telescope. It is said that after being dried for years, they will revive when placed in favorable conditions, though some authors think it is contained eggs that survive instead of the adults.

BRANCH MOLLUSCOIDA.

This group gets its name from the fact that some of the forms were once supposed to be mollusks. There are two principal classes.

The Polyzoa.—These are chiefly, though not entirely, marine and are known as the "sea mats" or "corallines." They are also known as the "moss animals." These names come from the fact that they grow in colonies like mosses. They often incrust rocks with their skeletons, which are either gelatinous, chitinous, or calcareous. Each individual is frequently contained in a sort of cup, into which it can retract or from which it can protrude to a certain extent. There is a row of tentacles around the mouth. One of our fresh-water forms (Pectinatella) has a gelatinous basis or common body, which is found in spherical masses as large as a man's head, being attached to branches in the water. The living animals are on the outside. Such masses are often called "sponges" by the fishermen.

FIG. 201. LAMP SHELLS (BRACHIOPODS).

The Brachiopods.—These are inclosed in a bivalve shell, and are named the "lamp shells." Their resemblance to mollusks is very superficial, the internal structure of the two being totally unlike. There is usually a circle of tentacles somewhat as in the Polyzoa. The brachiopods are exclusively marine. They are attached by a stalk which extends through the larger valve near the hinge. There are many fossil brachiopods.

CHAPTER XXIII.

CLASSIFICATION OF THE ANIMAL KINGDOM.

(Parker and Haswell.)

BRANCH I. — PRŌTŌZŌ'A.

Class I. Rhīzŏp'oda — Amœ ba, Glŏbigerī'na.
Class II. Mastigŏph'ora — Euglē'na, Vol'vox, Nŏctĭl'uca.
Class III. Spōrozō'a — Grĕgarī'na.
Class V. Infusō'ria — Paramē'cium, Vorticĕl'la.

BRANCH II. — PŌRĬF'ERA.

Class I. Pōrĭf'era — sponges, fresh-water and marine.

BRANCH III. — CŒLĔNTERĀ'TA.

Class I. Hȳdrozō'a — Hȳ'dra, sea anemone.
Class II. Scȳphozō'a — jellyfish.
Class III. Actinozō'a — corals.
Class IV. Ctĕnŏph'ora (ten-off'-o-ra) — comb jellies.

BRANCH IV. — PLĂTYHĔLMĬN'THES.

Class I. Turbellā'ria — planarian worms.
Class II. Trĕmatō'da — liver fluke.
Class III. Cĕstō'da — tapeworm.

BRANCH V. — NĔMATHĔLMĬN'THES.

Class I. Nĕmatō'da — roundworms, Trichina.

BRANCH VI. — TROCHĔLMĬN'THES.

Class I. Rotĭf'era — wheel animalcules.

Branch VII. — Molluscoi'da.

Class I. Pŏlyzō'a — sea mats.
Class II. Brăchiŏp'oda — lamp shells.

Branch VIII. — Ĕchĭnōdĕr'mata.

Class I. Asteroi'dea — starfish.
Class II. Ophiuroi'dea — brittle stars.
Class III. Ĕchinoi'dea — sea urchins.
Class IV. Hŏlothuroi'dea — sea cucumbers.
Class V. Crīnoi'dea — sea lilies.

Branch IX. — Annulā'ta.

Class I. Chætŏp'oda (ke-top'-o-da) — earthworm.
Class II. Gephyrē'a (jef-e-rē'-a).
Class III. Hĭrudĭn'ea — leech.

Branch X. — Arthrŏp'oda.

Class I. Crustā'cea — crayfish, crab, barnacle, cyclops.
Class II. Mȳrĭăp'oda — centiped, milliped.
Class III. Insĕc'ta — grasshopper, dragon fly, water bug, butterfly.
- Order I. Thȳsanū'ra — small, wingless insects.
- Order II. Orthŏp'tera — grasshopper, cricket, cockroach.
- Order III. Odonā'ta — dragon fly, damsel fly.
- Order IV. Hemĭp'tera — water bug, squash bug, cicada.
- Order V. Neurop'tera — ant-lion.
- Order VI. Lĕpidŏp'tera — butterfly, moth.
- Order VII. Dĭp'tera — housefly, horse fly, flesh fly, mosquito.
- Order VIII. Cōleŏp'tera — May beetle, potato beetle, tiger beetle
- Order IX. Hȳmenŏp'tera — bee, wasp, ant, gallfly, ichneumon fly

Class IV. Arăch'nīda — spiders, ticks, mites, daddy longlegs.

Branch XI. — Mŏllŭs'ca.

Class I. Pelecȳp'oda — clam, oyster, scallop, mussel.
Class II. Amphineū'ra — chī'ton (kī'-ton).
Class III. Gastrŏp'oda — snails, fresh-water and marine.
Class IV. Cĕphalŏp'oda — squid, cuttlefish, oc'tōpus, nau'tilus.

BRANCH XII. — CHŎRDĀ′TA (kor-dā′-ta).

Subbranch I. Adĕlochŏr′da — Bălanōglŏs′sus.
Subbranch II. Ūrochŏr′da — sea squirts.
Subbranch III. Vĕrtēbrā′ta.
  Division A. Acrā′nia (without cranium) — lancelet.
  Division B. Craniā′ta — all other vertebrates.
Class I. Cȳclostŏm′ata — lamprey eels.
Class II. Pĭs′ces (pĭs′-sēz) — fishes.
  Subclass I. Elasmobrăn′chii — shark, ray.
  Subclass II. Hŏlocĕph′ali — Chimera.
  Subclass III. Teleos′tōmi.
    Order I. Crossopterygii — Polȳp′terus.
    Order II. Chondrostei — sturgeon.
    Order III. Holostei — gar pike, dogfish (of Central states).
    Order IV. Tēleŏs′tēi — most bony fishes, such as catfish, salmon, herring, mackerel, codfish, perch.
  Subclass IV. Dĭp′noi — lungfish.
Class III. Amphĭb′ia.
    Order I. Urodē′la — mud puppy, siren, salamander.
    Order II. Anū′ra — frog, toad.
    Order III. Gȳmnophiō′na — blind snake.
Class IV. Rĕptĭl′ia.
    Order I. Squamā′ta — lizard, snake.
    Order II. Chēlō′nia (ke-lō′-ni-a) — turtle.
    Order III. Crŏcōdĭl′ia — alligator, crocodile.
Class V. Ā′ves.
  Division A. Ratī′tæ (breastbone without keel) — emu, ostrich.
  Division B. Cărinā′tæ (breastbone keeled).
    Order I. Pȳgŏp′odes — loon, grebe.
    Order II. Impĕn′nes — penguins.
    Order III. Turbinā′res — pĕt′rels.
    Order IV. Steganŏp′odes — cormorant, pelican.
    Order V. Herōdiō′nes — heron, stork.
    Order VI. An′serēs — duck, goose.
    Order VII. Accĭp′itrēs — hawk, owl, vulture.
    Order VIII. Cryptūri — tinamou.
    Order IX. Gallī′næ — grouse, quail, turkey.
    Order X. Grăl′læ — rail, crane.
    Order XI. Gā′viæ — gull, tern.

Order XII. Līmĭc′ōlæ — snipe, plover.
Order XIII. Ptĕroclē′tēs — sand grouse.
Order XIV. Cōlŭm′bæ — pigeon, dove.
Order XV. Psit′tacī (sit′-a-si) — parrot, cockatoo.
Order XVI. Strī′ges (strī′-jēz) — owls.
Order XVII. Pīcā′riæ — woodpecker, cuckoo, humming bird.
Order XVIII. Păs′serēs — robin, lark, sparrow, thrush, crow.

Class VI. Mămmā′lia.
Subclass I. Prōtōthē′ria — duckbill, spiny ant-eater.
Subclass II. Thē′ria.
Section A. Mĕtathē′ria (marsupials) — opossum, kangaroo.
Section B. Euthē′ria.
Order I. Edentā′ta — sloth, ant-eater
Order II. Cetā′cea — whale, porpoise, dolphin.
Order III. Sirē′nia — manatee, dugong.
Order IV. Ungulā′ta: —
Odd-toed (Perĭssodac′tyls) — horse, tapir, elephant
Even-toed (Artiodac′tyls) — ox, sheep, deer, pig.
Order V. Carnĭv′ora — dog, cat, bear, wolf, fox, seal.
Order VI. Rōdĕn′tia — rat, mouse, rabbit, squirrel.
Order VII. Insectĭv′ora — mole, shrew, hedgehog.
Order VIII. Chirŏp′tera — bat.
Order IX. Prī′mates — lemur, baboon, ape, man.

INDEX TO PART I.

ZOÖLOGY

DESCRIPTIVE AND PRACTICAL

BY

BUEL P. COLTON, A.M.

AUTHOR OF "PHYSIOLOGY, EXPERIMENTAL AND DESCRIPTIVE," "PHYSIOLOGY: ILLUSTRATED BY EXPERIMENT," "ELEMENTARY PHYSIOLOGY," "PRACTICAL ZOÖLOGY"; AND PROFESSOR OF NATURAL SCIENCE IN THE ILLINOIS STATE NORMAL UNIVERSITY

Part II

PRACTICAL

D. C. HEATH & CO., PUBLISHERS

BOSTON NEW YORK CHICAGO

"If you study Nature indoors, when you go outdoors you cannot find her." — *Agassiz.*

"He is a good naturalist who knows his own parish thoroughly." — *Kingsley.*

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Printed in U. S. A

PREFACE.

THE principal change from the earlier edition consists in the addition of directions for field study and for the laboratory study of the live animals. In the nature of the work these directions must be somewhat general, and should be modified by the teacher to suit local conditions and the requirements of the class. Because of the fact that conditions greatly vary in different localities, it is not to be supposed that each teacher can accomplish all the work here outlined. It is hoped that there is variety enough to suit most localities. Other types may often serve the purpose better than these here presented. The work must also be adapted to the age and experience of the students and to the time allotted to the subject. The author's reasons for the order of study here presented are given in the preface of the descriptive part of the book.

For convenience, the practical part follows the descriptive text, but, of course, the actual study of the types should precede any assigned lesson or reading in reference books.

The "Suggestions to the Student" have been entirely rewritten.

The "Suggestions to the Teacher" have become so extended that they are no longer included in the book, but are printed in a separate pamphlet, which can be obtained of the publishers. In this pamphlet are hints as to laboratory equipment, classroom management, notes and drawings, supervision of dissection, collecting outfit, field work, preservation of material, etc.

A full-page cut of the microscope has been introduced to accompany the directions for its manipulation. The author takes this occasion to thank the firm of Bausch and Lomb for

their kindness in furnishing the electro for this cut. A few other cuts are added to illustrate the work of dissecting.

The importance of the actual study of types cannot be too strongly urged. Without some real knowledge derived from his own observation, the student has no foundation on which to build the structure of information that he gets from reading and from lectures. To a few fixed facts of experience he can firmly fasten that which he acquires through the experience of others, but which would otherwise be vague and fleeting.

The earlier edition of the author's "Practical Zoölogy" was corrected by the late Professor Alpheus Hyatt of the Boston Society of Natural History; President David Starr Jordan of Leland Stanford, Jr., University; Professor N. S. Shaler, Harvard University; Professor H. Garman, State College of Kentucky; Mr. B. H. Van Vleck; Mr. J. Y. Bergen, Jr., of the English High School, Boston; Professor R. E. Call; Mr. E. P. Jackson, Boston Latin School; and Professor L. M. Underwood, Columbia University.

The proofs of this edition have been critically read by Professors M. F. Arey, State Normal School, Cedar Falls, Ia.; A. C. Boyden, State Normal School, Bridgewater, Mass.; M. J. Elrod, University of Montana; J. W. Folsom, University of Illinois; H. Garman, State College of Kentucky; W. S. Jackman, University of Chicago; H. S. Jennings, University of Michigan; J. M. Johnson, Peter Cooper High School, New York; S. J. Hunter, University of Kansas; Louis Murbach, Detroit High School; Frank Smith, University of Illinois; H. B. Ward, University of Nebraska.

The directions for the study of the honey-bee were written by Mr. Charles H. Allen, Bloomington, Ill., High School.

To these gentlemen the author is deeply indebted, and offers them his most sincere thanks.

CONTENTS.

INTRODUCTION.

TO THE STUDENT.

Class-room Notes. — You should make careful notes of all your observations and work, both in the class room and the field. The temporary notes may be written with a pencil in any convenient notebook. The following plan, however, is recommended. Get a pad of unruled paper, about six inches long and four inches wide. On this, the notes and temporary drawings are to be made, using only one side of the paper. Remove the sheets as they are filled. Keep them in a strong manilla paper envelope, half an inch wider and an inch shorter than the sheets. Label the envelope "Zoölogy"; or, better, have a number of envelopes labeled with any convenient subdivisions of the subject. As much or as little of the notes as desired may be carried. These envelopes can be carried in the pocket, and the notes are available at short notice, and can be consulted many times where a notebook, with all the notes of a term, would not be at hand. A still further advantage is that any notes or drawings on the same subject, made later, can be inserted at the right place, which could not well be done with a regular bound notebook. As the notes accumulate those not in immediate use may be stored in larger envelopes and kept as best suits your convenience. A part of the "pad" of note paper should be carried to all class-room exercises, whether it be a laboratory exercise or a recitation, to take any needed notes. Record should be made of all animals studied, whether those given to students for detailed examination or dissection, or the exhibition specimens brought in from day to day. Many statements made by teacher

or fellow-pupil are worth copying in the notes. Notes should also be made of your reading about the animals that are brought in.

Field Notes. — For field notes a well-bound notebook is usually better. It should be leather-covered and smaller than the class-room note paper. In this book you should make record of your outdoor observations. In the directions for "Field Study" are many questions for you to answer. It is to be hoped that you will ask many other questions and record your answers. If you can give no immediate answer, do not give it up. Keep on looking and keep on thinking. Your "field notes," "outdoor study," "Saturday book," or whatever you choose to call it, should be your constant companion. If the book has not a loop to hold a pencil, see to it that you have two or three short stubs of pencil in your pockets.

Equipment for Field Work. — Suggestions will be found in connection with the field study of insects, birds, etc. But the student should always carry a convenient lens, for there are many specimens which ought to be examined when found. Almost any small, compact lens of moderate power will be sufficient, such as the linen-tester, which folds into very small space, the lenses in hard rubber or metal cases, etc. The tripod lens is rather inconvenient to carry in the field, but better than many others for class-room work. When possible, carry a field glass. It will enable you to bring close to you many birds and other animals that will not allow you to come close to them. Even if your excursion is for insects, or other specimens which you can easily approach, you do not know what opportunities you may have to see distant specimens. The modern field glasses, with prisms instead of lenses, are superior to those of the old style, and in addition are very light, hardly weighing more than ordinary opera glasses. They are, however, rather expensive. Common opera glasses serve very well for all the ordinary purposes of studying birds.

Permanent Notes. — The permanent notes should be written with ink on ruled paper ten inches long by eight inches wide.

The paper should be ruled on both sides, with ruled marginal spaces, an inch on one edge and an inch and a half on the other; the wider margin should be perforated for binding. For the drawings, good, unruled paper with the same marginal lines and perforations should be used. Pads of these two kinds of paper, with labeled covers, are furnished by school-supply dealers. This system allows any desired arrangement of the notes and drawings, irrespective of the time when they were made. They may also be put together temporarily in any way desired. When you hand in to your teacher any detached papers, write your name and the date on the perforated margin, where it will not mar the completed notes. On the cover should appear the subject, your name, the name of the school, and the date. Brief marginal headings are often helpful, to yourself as well as to your teacher. The permanent notes are usually to be derived from the temporary notes "revised and enlarged." They should be in your own words, and your very best language should be used. The notes should be not only accurate, but they should be interesting. Avoid long-drawn sentences. Brevity is the soul of wisdom as well as of wit.

Drawings. — These should first be made in pencil. Have a medium hard pencil and keep it sharp. Avoid shading, but make outline drawings. Make the first lines faint, and then, if they suit you, that is if they conform to the thing itself, go over them again and make them heavier. Make no line or mark that does not correspond to something you see in your specimen. Proceed slowly, and whenever you are dissatisfied erase the line, using the kneaded rubber eraser. Do not abandon the drawing to begin another; keep "doctoring" the drawing with which you start. Often it is desirable to make some feature more distinct than it appears in the specimen itself. For instance, in representing the back of a bug or a beetle, the mode of overlapping of the wings is the important fact to be brought out. But the line of union or of overlapping may be decidedly indistinct, whereas some ridge that is of no significance may be

prominent. Bring out the important features; often ignore features that are of no significance. Drawing should show structure rather than mere appearance. Represent things not so much as they appear, but rather as they really are. To make the suggestions more definite, suppose you are to make a drawing of the perch. Prop the fish up so you get a square view of its left side. In the first place the drawing should be of good size, so there will be room to put in details without having them crowded. About eight inches will be a good size to place lengthwise on the drawing paper. It is better to make the original drawing of the same size you wish for the finished drawing. Determine the place of the drawing on the sheet, leaving about equal space at each end, and with the drawing a little above the middle, as the general label should always be beneath the drawing. First draw a straight line for the longitudinal axis. Next determine where the greatest depth of the fish is, and draw a line, the transverse axis, at right angles to the main axis. Note carefully whether or not the transverse axis is divided into two equal parts by the longitudinal axis, *i.e.* whether the body of the fish is more above or more below the main axis. Having these points located, proceed to draw the outlines of the fish, watching closely to see that you get the right proportions. Go no faster than you can give satisfaction to your own criticism. After completing the general outline, draw the lateral line. Then make a dot for the hindmost tip of the gill cover, which marks the posterior end of the head. Proceed to put in the details of the head, the parts of the gill cover, the mouth, the eye, etc. In drawing the mouth, show it as it is and be careful not to be guided by any preconceived notions of it. Block out and then fill in the different fins. Unless you have an abundance of time, do not attempt to represent the scales, and it is not essential to show the colors.

When the above features are satisfactory to you as drawn in pencil, proceed to trace over the lines with ink. This is not so easy, as you cannot readily erase. Have confidence in the

steadiness of your hand and you will probably get along all right. Use a good, black drawing ink, and a clean, fine-pointed pen. Trace from left to right, drawing the pen slanting well back so it will slide easily. Work always on the "out curve," — *i.e.* supposing the drawing is right side up, begin at the head and trace the outline of the back; when you have reached the tail, turn the drawing upside down, and trace the ventral margin, beginning with the tail end. By this method you will always be making an easy curve, with the elbow as the center of the curve. Follow this plan wherever there is a curved line, always turning the drawing so that the concave side of the curve is toward you. Try to give an even, steady motion. Whenever possible avoid going over the line a second time with the pen. If necessary to trace over, or especially if you stop to re-ink, begin a little back of where you stopped, in order to make the line smooth and even. If you attempt to trace by pushing the pen, or even by drawing it sidewise, it may occasionally "stick and sputter"; drawing the pen lengthwise, as above suggested, seldom makes any such trouble.

Now comes the labeling. Place the label on each part, or very close to it. Never letter, or number, the parts, with explanations below. This method is wasteful of time and eyesight. Plan the labeling carefully before you begin. Do not make the labels crowded in one part and scattered in another if you can distribute them more evenly. Avoid drawing a dotted line across one organ to the one designated. Organs near the margin may well be labeled outside, using dotted lines if necessary. Organs far from the outside are best labeled on the organ itself in the most available place. Print all labels, using the gothic type, that is, without crosses at the ends of the lines. To insure uniformity in the letters make parallel guide lines with the pencil; then letter with pencil; after tracing the letters with ink, erase the guide lines. The general label, below, should be larger than the detail labels. See the cut of the perch as an example of labeling.

If water-color drawings are to be made, first draw the outlines in black ink. After this is dry, paint in the water color. Do not use colored pencil crayons. Only solid organs, such as the liver, should be represented in solid color. Hollow organs, such as the digestive tube, should be represented in outline to show that they are open. The following colors may be taken to represent the different systems: arteries, red; veins, blue; digestive tube, brown; liver, green; kidneys, purple; lungs, pink; nervous system, gray; reproductive glands, orange.

Do not be discouraged if your first drawings do not satisfy you. Drawing requires time and patience. Without these even the most gifted artist produces nothing worthy. The majority of students say at first, "I can't draw." After some suggestions, and a little practice, almost every one can show creditable results. The first thing is to *see clearly*. See each line in the specimen, and make each mark in your mind, before you put it on paper. In such simple drawings as are here required, failure to draw well, after a little experience, usually indicates failure to see well. It is more head work than hand work. Perhaps the best definition of drawing is that given by the little girl who said "drawing is thinking, and then marking around the think."

Dissecting. — The instruments needed are: a pair of scissors, a pair of forceps with roughened tips that will hold objects securely, a scalpel, a cartilage knife, a blowpipe, two dissecting needles, and a lens. The needles may be made by thrusting the eye end of a strong needle into a wooden handle. These instruments are usually sold in sets in a convenient carrying case; the cloth-lined leatherette cases are more compact than the wooden boxes. The cutting instruments should be kept sharp, for which a small oilstone is desirable. Often the reason why scissors do not cut is because they are loose at the joint. They should sharply snip a hair, or thin paper, at the very tip of the blades. Avoid straining the scissors by trying to cut tough or hard objects near the tip; cut such things near the joint. Use the cartilage knife for the rougher work, where you are likely to

strike bone; keep the scalpel for the finer work. Be careful to keep the joint of the scissors dry. Do not get blood in it while dissecting, nor water when cleaning. If the joint is kept well oiled, watery liquids are usually kept out. Always clean the instruments after dissecting, using no more water than is needed; often a moist cloth will be sufficient. See that they are dry before you put them away. If they are to remain unused for some time, rub them with an oiled rag, or slightly smear them with vaseline.

The scissors should be used much more than the beginner would suppose. All small objects and especially thin membranes are better cut with the scissors than with the scalpel, for the reason that each blade of the scissors holds the object for the other blade, whereas the knife tends to push out of the way the object to be cut, and often leads to the cutting of underlying tissues that should be left uninjured. While cutting with one hand, whether with scalpel or scissors, always use the forceps in the other hand to steady the object, and especially to hold the edge while cutting any thin membrane. This is especially necessary when cutting through the wall into any cavity. Hold the forceps as you would a pen, and not as a pair of tongs. Delicacy and not strength is required. By holding the forceps as you would a pen, you keep the wrist down in a restful position, and can often let it rest on the edge of the dissecting pan; your hand is thus less likely to be in your light. Do not touch objects with a blade of a cutting instrument unless you intend to cut them. If you wish to push an organ aside, or turn it over, use the fingers, forceps, or the handle of the scalpel. In much of the dissecting the handle of the scalpel should be used, chisel-fashion, scraping and pushing, rather than cutting. In fact, the handle of the scalpel should be used more than the blade. Many tissues are tough and will stand dragging or tearing, whereas a slight cut will cause bleeding enough to interfere seriously with the work, not only making the work unsightly, but obscuring the view. This is especially

true of such delicate tissues as that of the liver. The blowpipe should be used to inflate thin-walled tubes and cavities. It is also useful as a probe. A piece of copper wire, or an aluminum hairpin straightened out and tipped with sealing wax, serves well as a probe. For tracing very slender ducts use a bristle tipped with a very small drop of sealing wax. When dissecting specimens under water do not lift the specimen out to see anything. The soft tissues sink down together in a mass that prevents seeing as well as before, whereas while under water they are partly floated up and thus made more distinct. It may be necessary, however, occasionally to lift the specimen from the water to make a cut near the ends, or to make some new adjustment, as inflating through the mouth. Always follow directions closely when dissecting. By not doing so you are likely to waste both time and material. Read the whole sentence before making a new cut. It is a good rule not to cut anything unless you know what it is. Keep your thinker just ahead of your cutter. If in doubt, ask help of your teacher.

General Suggestions. — Arrange your table, and your position, so as to get enough, but not too much, light. If two work together, be careful not to let the heads or hands shut out needed light. At the beginning of the term learn the rules regulating the laboratory, and carefully observe them. But whatever the rules, be sure and keep your own table neat and clean. If other students use the same table, put away all your belongings. If you have the exclusive use of it, keep books, instruments, etc., in order. Take pride in making your notes and drawings the best possible. The book is yours to keep, and, if well done, will likely be useful to you later. It is a worthy ambition to desire to excel. In all your work, *think* about what you are doing. Do not let yourself drift along thoughtlessly. No work succeeds without live interest in it, and thoughtful attention. Try to think out the use of each part or organ, the ways in which the animal is adapted to its place of living and to all its surroundings. This habit of thinking about the things you are

working over will fill them with an interesting meaning, and the work will cease to be drudgery and become a source of increasing entertainment.

Books of Reference.

1. The American Natural History, Hornaday.
2. Riverside Natural History, Kingsley.
3. A Manual for the Study of Insects, Comstock.
4. Key to the Birds of North America, Coues.
5. Manual of the Vertebrates, Jordan.
6. A Naturalist's Rambles about Home, Abbott.
7. Animal Life, Jordan and Kellogg.

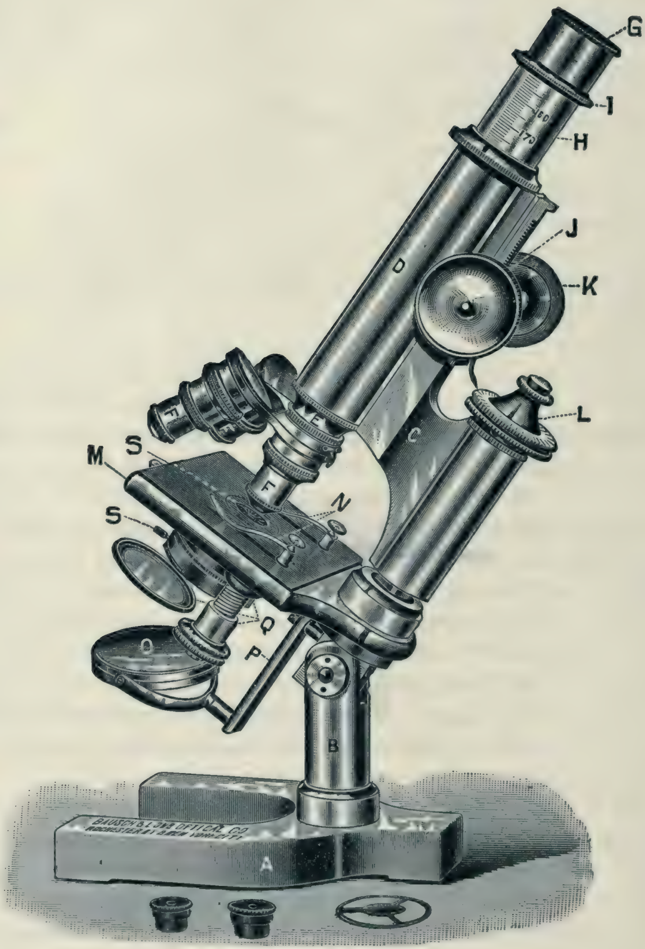
The first five of these should be used for reference. Each student ought to read the last two.

USE OF THE MICROSCOPE.

General Rules. — 1. Do not touch lenses, nor allow them to touch anything. 2. Keep the instrument away from dust. 3. If dust gets on a lens blow off as much as you can and then wipe with chamois skin, or clean soft cloth, such as old linen. Handle the microscope by the pillar below the stage.

Setting up a Microscope. — The eyepiece should slip easily into place by its own weight. To attach an objective, first run the tube up by the coarse adjustment, till the lower end of the tube is two or three inches from the stage. Then hold the objective with the thumb and finger of one hand while the other hand screws it to place. See that the threads catch fairly; do not use force or you may ruin the threads. Take care not to touch the lens.

Use of a Low-power Objective. — Place on the stage a slide holding a mounted preparation. Slip the ends of the slide under the clips. Place the specimen over the center of the hole in the stage. Turn the mirror so that it throws light through the hole upon the mounted object. Lower your head to the level of the stage and watch while running the tube down by the coarse adjustment; stop when the objective is a quarter of an inch from the glass slide. Take hold of the milled head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of the coarse adjustment; look through the eyepiece and slowly raise the tube until you see the object distinctly. Move the slide till the object, or the part you wish to examine, is in the center of the field of view. Now use the fine adjustment. Never turn the milled head of the fine adjustment more than two or three turns in either direction.

Use of a High-power Objective. — Begin as with the use of a low-power objective. Lower the tube until the objective almost touches the cover glass, watching closely with your head down on a level with the stage. Look through the eyepiece; by means of the coarse adjustment, slowly raise the tube till the object comes into view. Then use the fine adjustment till the outlines become sharp and distinct. Be very careful not to run the objective against the cover glass. If you do this, you may ruin the preparation and injure the lens.

The Diaphragm. — Use an opening in the diaphragm of about the same size as the front lens of the objective.

Use of the Eyes. — Always keep both eyes open when using a microscope. This may be a little confusing at first, but you will soon learn to ignore what the other eye sees.

Read "Practical Methods in Microscopy," Clark (D. C. Heath & Co.).

Parts of a Microscope.

A. Base.
B. Pillar.
C. Arm.
D. Body.
E. Nose piece.
F. Objective.
G. Eyepiece.
H. Draw tube.
I. Collar.
J. Coarse adjustment.
K. Milled head of coarse adjustment.
L. Micrometer screw of fine adjustment.
M. Stage.
N. Clips.
O. Mirror.
P. Mirror bar.
Q. Substage.
S. Diaphragm.

ZOÖLOGY: DESCRIPTIVE AND PRACTICAL.

PART II. PRACTICAL.

CHAPTER I.

COLLECTING INSECTS.

Apparatus. — 1. *Killing Bottle*. Get a wide-mouthed bottle, two or three inches wide and five or six inches high, with a good, sound cork which fits well; half a pint of plaster of Paris; and a lump of cyanide of potassium, about an inch square and half an inch thick, though the equivalent of this in smaller pieces serves as well or even better. In handling the cyanide of potassium great care must be observed, for it is a violent poison; not only is it a stomach poison and a blood poison, but even its fumes are poisonous. It is much safer to handle it with forceps, or, if these are not at hand, pick it up with a piece of paper. Lay the pieces of cyanide of potassium in the bottom of the bottle, and pour in just enough water to cover them; then sift in plaster of Paris till the water is all taken up. The bottle should be left uncorked for a few hours; during this time it should be set away where it can harm no one, for the poisonous fumes will escape. If any loose plaster of Paris remains, empty it out; cork the bottle tightly. It should be labeled "poison" and kept out of reach of children. Such a bottle is usually called a "cyanide bottle."

Insects may also be killed by chloroform, by putting a few drops into a bottle with the insect. This method is desirable for

moths and butterflies, which often become damaged in a cyanide bottle. A drop or two of gasoline placed on the thorax and abdomen of an insect will usually kill it quickly and not injure it. Hard-bodied insects, such as beetles, may be dropped at once into weak alcohol; but this would not do for delicate insects, such as butterflies.

Many insects may be captured directly in the bottle; especially is this convenient when insects are found on leaves and flowers. Bring the bottle up under the insect with one hand; with the cork in the other hand quickly push the insect into the bottle. This is very desirable in capturing bees or other stinging insects, ill-smelling bugs, blister beetles, etc.

2. *Insect Net.* Get a light wooden handle about three feet long, and the same length of No. 8 brass wire. Bend the wire into a circle about ten inches in diameter, cross the ends, and bend them so that after crossing they will extend alongside the handle. Bend each end at a right angle, so it may be driven into the handle to keep it from slipping off. Cut a notch in the end of the handle, fit the ring to it, and bind it on firmly with fine wire. The common error is to get too long and heavy a handle. A light, quick swing will secure more insects than a long reach. A piece of cane pole would be excellent if a ferrule were made to fit over the end; otherwise it would be likely to split. The bag should be of cheese cloth or Swiss, about eighteen inches deep and rounded at the bottom. The net is likely to become frayed out along the ring, from striking over bushes; hence it is best to sew a strip of strong muslin along the ring, and then sew the bag to this strip. When a flying insect, such as a butterfly, is caught, the net should be thrown over to one side by a quick turn of the wrist, so the insect cannot escape. Often the collector is more successful if, instead of running down a butterfly, he watches it till it lights, and then quietly claps the net over it. After the insect is caught in the net, the bottle, uncorked, may be pushed into the net and around the insect, or the insect pushed into the bottle by means of the cork. Many specimens may be obtained

by sweeping the net along over the top of the grass and over the tops of bushes, even where no insects are seen.

3. *Boxes.* The collector should also carry an extra bottle or a box or two, into which insects may be put after they have been killed. This makes room for new insects in the cyanide bottle, and keeps them better, as the newly introduced specimens sometimes struggle and may injure other specimens. Baking-powder cans and cocoa boxes are very convenient. A shallow cigar box is good for butterflies, as they may be pinned to the bottom so they will not slip about and be injured.

4. *Shell Bag.* For carrying the above apparatus, the most convenient thing is what is known as a shell bag. It is of strong canvas, and provided with a good shoulder strap. Ordinary pockets do not serve well for all the needed material. While the net is in use, the bottle and the boxes may all be safely held in the bag and out of the way of the arms and hands. The common "schoolbook bag" may be used, but they are often very weak, and likely to give way when one is forcing his way through weeds and bushes, and may be lost without being noticed. A good shell bag will last almost a lifetime for this work.

General Suggestions on Collecting. — For most insects the best time is in the middle part of a bright, warm day, for insects are most active in warm weather. But one should not neglect collecting on dark or cold days. At such times one may learn where insects hide. Not only the places where insects hide, but their colors and positions should be carefully noted, as these help to conceal them. Turn over boards, stones, and pieces of bark; pry off pieces of loose bark from logs and stumps; kick to pieces rotten stumps; and look into the crevices in fences, and about porches, etc., for insects in hiding. Careful work will secure many specimens on days when almost no insects are seen moving, and when the casual observer would say that there are none to be found. Butterflies are well kept in a fold of paper as follows: Take a piece of paper two inches longer than wide; three and a half by five and a half inches is large enough for most specimens.

Fold the paper diagonally, with about an inch of each end projecting; drop the butterfly in, and fold the edges over to keep it from slipping out. This may safely be carried in a box, a pocketbook, notebook, or inside the sweat band of the hat. If one catches an insect, with no other way of carrying it, it may be pinned into the crown of the hat on the inside; here is room for it, and no one will be likely to notice the projecting tip of the pin. An umbrella may be very useful in collecting. Hold the umbrella spread and inverted under the branches of shrubs and trees, and beat the branches with a stick, or jerk them with the handle, if it has a hook.

Collecting by Artificial Light. — A lamp at a window, as when studying, often brings valuable specimens. Electric lights along the streets draw swarms of insects. It will pay the collector to visit a number of lamps during the evening. Early in the morning one may find some specimens, though many will have flown or crawled away, and some may have been ruined by being trampled upon.

Sugaring. — Many moths fly only at night. A favorite method of capturing these is to make a thick sirup of brown sugar; daub this on the bark of trees, then visit these places to catch the moths feeding on the sweet bait. The collector sets a series of these baits, as a trapper sets a "line" of traps, and visits them in series. A lantern should be carried; the ordinary lantern serves about as well as a dark lantern. Sometimes the bottle can be put over the moth before it attempts to escape. In this way some of the finest night moths are taken, and of kinds that are rarely seen in the daytime.

Breeding Cages. — All the foregoing modes of capture are likely to injure the specimens. The surest way to get perfect specimens is to rear them. For this one may gather the cocoons and keep them till the insects emerge. Better still, get the larvæ, keep them and supply them with food till they spin their cocoons, or go into the pupa stage; then one can be sure he knows the

kind of larva from which any given adult comes. There are many adult insects whose larval stage is unknown, or little understood.

When a caterpillar or other larva is taken, the collector should note on what it is feeding, and it should be supplied with the same, or very similar, food, as long as it continues to eat. If the larva is not on any plant, but is crawling over a walk or on a fence, it may be because it was shaken off the plant on which it was feeding; very often, however, the larva, when thus found, has done eating and is seeking a convenient place to go into the pupa stage. If so, it will not need food. It is safe to offer food in any case.

Larvæ should be kept in roomy cages. And, since many larvæ go into the soil to pass their pupa stage, it is best to provide soil for any larva whose habits are not known. A convenient breeding cage may be made of a starch box by sawing off about one third of the length of the wooden cover and sliding it into the farthest end of the top. Then set the box on end, with this covered part down, and fill with soil as far as the wooden cover extends. Cut a glass cover to slide in and fill the rest of the opening; make a hole for ventilation and cover it with wire screen. If a larva that does not pupate underground is reared in such a box, no harm will result. It is well to have several such boxes in readiness for the work. A jelly tumbler serves very well as a breeding cage for small insects. A lamp chimney may be used as a breeding cage; tie netting over the top.

PRESERVATION OF INSECTS.

Pinning. — Most insects are mounted upon a pin passed through the center of the thorax. One third of the pin should project above the back. Beetles are usually pinned through the right wing cover, at such distance from the base of the wing that the pin emerges between the second and third pairs of legs. It is better to get regular insect pins, which are to be obtained from dealers in naturalists' supplies. Common pins may be used, but they are likely to rust. Medium-sized insect pins are best for

most specimens (No. 4, Kläger), though, if an extensive collection is to be made, there should be an assortment of pins.

Labeling. — The name of the insect, with date and locality, should be on a small label, on the pin about halfway between the insect and the bottom of the box. The name of the order or family should be at the beginning of the group, whether this occupies a whole box or less.

Boxes. — For ordinary small collections, the common cigar boxes are very convenient. Pupils can usually get them for nothing. The bottom should be lined with sheet cork, or thin slices of common corks can be fastened in at the place where the insects are to be pinned. It is best to devote a box to each order of insects, or even to families where many insects are collected. The boxes should be labeled on the outside near one end, so that they may be set on end on a shelf, and the label will show like the title on the back of a book. A set of shelves should be made of the right hight to accommodate the boxes as thus set on end.

Spreading Insects. — Beetles, bugs, flies, etc., are usually mounted with the wings folded. But the wings of moths, butterflies, dragon flies, etc., should be spread. And it is well to mount some locusts, beetles, bugs, etc., with the wings spread, for the sake of comparison.

Spreading Boards. — For spreading the wings of insects, a spreading board or setting board is used. This consists of two strips of soft board, fastened to a base, with a groove between them for the body of the insect, while the wings rest on the two side strips. At the bottom of the groove there should be a strip of cork to receive the pin. Place the insect in the groove, pinned firmly to the cork. Then insert a pin into the wing, back of the large veins, near the anterior border, and draw the wings forward until the hinder borders of the two hind wings are in a straight line. First fasten the wings in this position with narrow strips of paper held by pins. Then place a larger piece of paper over the wings and pin firmly. Sometimes strips of mica are used instead

of paper. Sometimes strips of glass are used, the weight being enough to hold the wings in place.

Relaxing Insects. — If insects become dry before they are spread there is danger of breaking them. They need softening. This is done by placing them in a moist place. They may be placed on dry paper over wet sand; or put wet paper into a jar, lay dry paper over this, and place the insects on the dry paper and cap the jar tightly. In a day or two they will be relaxed so they may be safely handled. A few drops of carbolic acid will retard the growth of mold.

Mounting Microscopic Insects. — Minute insects, such as fleas, or small parts of insects, such as an eye, leg, sting of a bee, etc., can readily be mounted and permanently preserved, ready for examination at any time. Such material should first be placed in alcohol. If it is soft material it should first be put into fifty per cent alcohol, in which it should not remain more than half a day; then it should be transferred to seventy-five per cent alcohol for twenty-four hours, and then kept in strong (ninety-five per cent) alcohol till ready for mounting. Pour a small quantity of oil of cloves into a watch glass and place the object to be mounted in it; this is to remove the alcohol and make it clear. Then lay it on the center of a slide in the desired position, cover it with a drop of Canada balsam, and lay a clean cover glass on it. Keep it on a level surface, so the cover glass will not slip, for a few days till the balsam has hardened. Label it at one end of the slide and keep in a suitable tray.

GENERAL PLAN FOR FIELD STUDY OF INSECTS.

Insects vary so greatly that no one plan of study will serve well for all. But the following scheme will serve in a general way for the main line of work, which must be varied to suit special cases.

Find out by direct and continuous observations in the field: —

1. Where does the insect live? On the ground? In water? On plants? If the latter, does it stay mostly on the stem or on the leaves?

2. What is its fitness for its place of living?

a. In locomotion. Does it swim, creep, walk, jump, or fly? Or has it more than one of these modes of locomotion? How is it fitted for moving?

b. General form. Is it slender or stout? Rough or smooth? Does it fold the wings when at rest, or keep them extended? Why?

c. Color. How is its color related to that of its surroundings? Would some other color be as suitable for it?

3. What does it eat? What kind of mouth parts has it, and how are they adapted for the food? Does it eat little or much? Does it store food, or depend on foraging daily?

4. Does the insect grow? If so, is the growth like that of other animals?

5. What enemies has this insect? How does it escape or avoid them?

6. Has this insect a home? Or any regular place to which it resorts? Where does it stay at night? In rough weather? Does it work by day or at night?

7. Does it lead a solitary life? Or is it social? If social, to what extent is there division of labor in the community?

8. How many kinds of insects in the community? How do the sexes differ in appearance, structure, and habits?

9. Do they live over winter? What provision is there for the continuation of the species? How long does an individual live? Are the different forms equally long-lived?

10. What are the stages of its development? Is there a metamorphosis, or merely an increase in size? How long is it in reaching maturity?

11. What senses does it use in its daily round? Are these well developed? Has it a sense of direction? Does it ever get lost?

12. If it visits plants, does it show preference for any particular plant? Does it visit many kinds of plants? What does it get from the plant? Does it do the plant any harm? Does it do the plant any good?

13. Can it display any colors that are ordinarily concealed? If so, why is this? How are such colors concealed?

14. Does this insect resemble any insect of another group? If there is resemblance, is it of any advantage?

15. How do insects compare with other animals in strength?

CHAPTER II.

INSECTA.

THE GRASSHOPPER.

The Parts of the Body.

(1) The foremost, or **anterior**, part is the **head**. (2) The middle part is the **thorax**. (3) The hinder, or **posterior**, ringed part is the **abdomen**.

THE HEAD.

1. Describe its shape and mode of attachment to the thorax.

2. The two slender projections are the feelers, or **antennæ**. Observe how and where they are attached to the head. Use a lens to count the parts, or **segments**, of which each antenna is composed.

3. Note the situation and shape of the eyes. Examine one of the eyes under a microscope, using a one-inch objective; make a drawing of what you see. These eyes are **compound**, and each of the parts is called a **facet**.

4. Just in front of the compound eyes look for a pair of the simple eyes, the **ocelli**. Find a third ocellus on the head, using a lens if necessary.

5. At the lower part of the front of the head is a movable flap, the upper lip, or **labrum**; raise it with the dissecting needle. Observe how it is hinged; cut or break it off.

6. This lays bare the true jaws, or **mandibles**. Examine their black, toothed tips with a lens; find, by prying, how they move. Study their action in the live grasshopper, raising the labrum. Study carefully the way in which they move, and how they are hinged; then remove with the forceps, and again examine thoroughly.

7. Turn now to the back of the lower part of the head; pry back the lower lip, the **labium**; carefully remove it.

8. At the base of the labium is the brown **tongue.**

9. Attached to the base of the labium is a pair of short, jointed appendages, the **labial palps.** What is the relation between the tongue and the labium?

10. If the above-named parts have been carefully removed, there will remain one pair of appendages, smaller jaws, called the **maxillæ.** Make out that each maxilla consists of three parts: —

a. An outer, jointed part, the **maxillary palp.**

b. A spoon-shaped piece covering *c.*

c. The brown, incurved maxilla proper. Examine with a lens, then with forceps remove the whole maxilla, being sure to get the basal part.

11. Cut the head off a fresh specimen; lay it on the table and make a careful drawing of the face, naming all the parts.

12. Draw the head as seen from the side.

THE THORAX.

1. The wide collar, or cape, back of the head is the main part of the **prothorax**; make a drawing of it as seen from the side.

2. The remainder of the thorax is formed by the union of two parts, each bearing a pair of legs, the part to which the middle pair of legs is attached being the **mesothorax,** the hinder legs arising from the **metathorax.** Look for the line separating these two parts of the thorax.

3. Look just above the second pair of legs for a narrow opening, guarded by a pair of lips, which, in the live grasshopper, keep opening and closing; this is a breathing pore, or **spiracle.** Look for another spiracle on the soft skin under the posterior edge of the prothorax on each side.

4. Carefully compare the prothorax, mesothorax, and metathorax in size, shape, and structure.

THE WINGS.

1. Notice the position of the outer (upper or anterior) wings, and their mode of overlapping.

2. With the forceps seize one of the outer wings by its lower edge, near the anterior end, and draw it horizontally forward, till it makes a right angle with the body, and pin in this position. Seize the inner wing by its lower edge near the posterior end, and pull forward to its fullest extent, observing how it is folded; pin this wing as expanded, and make a drawing of both wings as thus seen. Cut a piece of paper the same size and shape as the inner wing, and fold it as the inner wing is folded.

3. The framework of the wings is composed of **veins.**

4. Compare the inner and outer wings in size, shape, color, texture, position, and use.

THE LEGS.

1. Note their number, arrangement, and mode of attachment.

2. Study carefully one of the hind legs.

a. A short segment, near the body, is the **coxa.**

b. A smaller segment is the **trochanter.**

c. The large segment is the **femur.**

d. The slender segment is the **tibia.**

e. The remainder is the foot, or **tarsus**; count its segments, and examine thoroughly, using a lens. Examine the joint between the femur and tibia, moving the parts back and forth. Note, also, how these parts fit together when the leg is drawn up. Remove a hind leg, and make a drawing showing all these parts.

3. In how many ways does the grasshopper travel? In what order are the legs moved in walking?

4. Grasshoppers make a shrill sound (stridulation) by rubbing the inner surfaces of the hind legs against the outer wings.

5. In what different ways does the grasshopper keep from slipping when it jumps? Remove the legs and wings; make drawings of the thorax as seen from the side, from above, and from below.

THE ABDOMEN.

1. Count the abdominal rings.

2. Observe two grooves running along the under surface of the

abdomen. The under part of the abdomen, included between these grooves, is the **sternum**, the side of the abdomen is called the **pleurum**, and the upper part is the **tergum.**

3. Just above the groove that separates the sternum from the pleurum is a row of small holes, the breathing pores, or **spiracles**; count them.

4. In a live specimen, watch the movements of breathing. All insects breathe by means of a complicated system of air tubes, the **tracheæ**, which branch from the spiracles throughout the body. Can the grasshopper be drowned by holding its head under water? Connected with the air tubes, in grasshoppers and other strong flying insects, as bees and flies, are large air sacs, which fill with air, and are said to aid, like balloons, in keeping the insect in the air. By carefully cutting away the roof of the abdomen, these air sacs may be seen, marked by their white walls; the white air tubes, or tracheæ, may also be readily seen.

5. Under the bases of the wings, on the first abdominal ring, is a pair of thin, shiny, oval membranes, the **tympana,** or eardrums. The inner surface of each tympanum is connected with a nerve.

6. The abdomen of the female ends in four points; in laying the eggs these points are first pressed together, then thrust into the ground, and then separated; this process is repeated till a hole is made, sometimes as deep as the abdomen is long, at the bottom of which the eggs are deposited, passing out between the four points, which together are called the **ovipositor**. The males are smaller than the females. Draw the abdomen, as seen from the sides, of both the male and the female. Take now an entire specimen and draw a side view of it.

INTERNAL STRUCTURE OF THE GRASSHOPPER.

This work would better be done after the student has dissected the crayfish. Dissect under water in the dissecting pan.

1. Get a large female grasshopper, freshly killed. Cut off the wings, and place the specimen, back uppermost, in the dissecting

pan; pin the hindermost ring of the abdomen firmly to the bottom of the dissecting pan; turn each hind leg outward and pin down. With sharp, fine-pointed scissors, cut through each side of the roof of the next to the last abdominal ring; lift, with the forceps, the cover of this ring; continue to cut forward, on each side of the abdomen, pulling the tergum upward and forward as it is loosened. Thus carefully unroof the whole abdomen.

2. The heart is a delicate tube, running along just under the tergum, and probably was torn away with the tergum.

3. On each side there is a row of air sacs, with their white air tubes.

4. In the anterior part of the abdomen a mass of yellow eggs is usually to be found; this mass may be easily separated into two parts, right and left, from each of which a tube, the **oviduct,** leads to an opening between the parts of the ovipositor.

5. Under the eggs is the dark **intestine,** running lengthwise.

6. Remove the roof of the thorax; more air sacs should be found here. In the upper part of the thorax are the white **muscles** which move the wings. Removing these muscles exposes more of the digestive tube; as the food is swallowed, it passes upward into a brown tube, which soon turns backward into the thorax; in the prothorax, the enlargement is the **crop,** in which is produced the dark liquid which the grasshopper ejects from the mouth when held captive. The crop may be removed, split open, washed, and examined under the microscope with a half-inch objective to show the rows of hooked teeth with which it is provided. A little farther back the digestive tube is surrounded by a set of double cone-shaped pouches, which extend parallel with the main channel of the digestive tube. These are the **gastric ceca.** Behind them is the stomach, followed by the intestine. The products of digestion pass through the coatings of the digestive tube, and mingle with the currents of blood which pass along the ventral and lateral parts of the body.

7. The veins of the wings are air tubes, and are very different from the veins in our bodies.

8. The nervous system of the grasshopper consists mainly of a white cord extending along the floor of the whole body cavity. In most of the abdominal rings the nerve cord has enlargements called **ganglions,** from which nerves branch to the surrounding parts.

THE DEVELOPMENT OF THE GRASSHOPPER.

1. Late in summer watch grasshoppers to discover the process of laying eggs. If the eggs can be obtained, keep them till they hatch, and watch the growth of the young.

2. Early in the season catch a number of as young grasshoppers as you can find; cage and feed them, and watch their growth. What changes take place during development?

GRASSHOPPER CARD.

Take a card six inches by four. Make a faint mark lengthwise in the middle to aid in placing the parts symmetrically. Separate the parts of the grasshopper, and place them on the card in their proper order. Before beginning, plan the whole arrangement. First, cut off the head; leaving a central place for the head, remove the mouth parts, pasting each to the card as it is removed. In separating the parts use the forceps, being careful to get hold of the very base of each piece; then, holding each part with the forceps, dip the side that is to go next to the paper into the glue, and carefully place just where it is to stay. This method avoids smearing the card. Avoid getting too much glue. The mouth parts should surround the head; the wings should be opposite the parts to which they were attached, as also the legs. The legs should be separated to show all the segments; the thorax should be separated into its parts, but the abdomen would better be kept entire. As the parts become very brittle when dry, it is well, if the card is to be kept, to make a little bridge of a slip of paper, on which to string the rings of the thorax and abdomen. The soft parts should, of course, be removed. To preserve the card, place it in a shallow box and fasten it to the

bottom. Perhaps the best way is to make a glass cover to the box and then seal it, dust and moth proof, by means of passe partout binding.

Topics for Reports. — The Rocky Mountain Locust Scourge. Cockroaches. The Mole Cricket. Walking Sticks. Katydids. The Praying Mantis.

CHAPTER III.

INSECTA (*Continued*).

THE CRICKET.

1. In what respects are the cricket and grasshopper alike?

2. In what respects do they differ?

3. The female cricket has a long, slender ovipositor. Compare its parts with the parts of the grasshopper's ovipositor, picking them apart with a dissecting needle. Use a lens.

4. A pair of tapering, jointed projections from the abdomen are the **stylets**. Of what use are the stylets?

5. Compare the wings of the male and female. Look on the under surface of the outer wings of the male for a vein, running crosswise, near the anterior end, which has on it a row of teeth. By rubbing this **file** on the veins of the other wing, the cricket makes its chirping noise. Watch crickets to see how the wings are managed during this process.

6. With a lens look for the so-called hearing organ on the tibia of each fore leg.

7. Make a drawing showing all that can be seen from above (dorsal view), and name all the parts shown.

Grasshoppers and crickets belong to the order of insects called **Orthoptera**, or straight-winged insects.

THE DRAGON FLY.

1. Compare the shape and relative size of the parts of body with those of other insects. In some dragon flies the eyes have as many as 12,500 facets each.

2. What kind of mouth parts has the dragon fly?

3. How does the dragon fly compare with other insects in power of flight? To what bird should the dragon fly be compared in its habits?

4. Has the dragon fly a sting? Is it dangerous to man in any way?

5. Watch the dragon fly dipping the end of its abdomen into the water to lay its eggs. Compare the ovipositor with that of the grasshopper.

6. The larva of the dragon fly is called a **nymph**. It may be found on the bottoms of ponds and streams, and is very noticeable on account of its wide head and prominent eyes, wide abdomen, and short wings.

7. When the larvæ are ready to transform, they crawl up out of the water, their skins split along the back, and the adult dragon flies escape, leaving their dry, empty skins, which may be found clinging to the stems of water plants, projecting logs, or rocks.

8. Draw a dorsal view.

9. The dragon fly belongs to the order **Odonata**, or nerve-winged insects.

THE SQUASH BUG.

1. Find the sucking tube bent back under the thorax.

2. Are there both simple and compound eyes?

3. What peculiarities of the prothorax?

4. Draw a dorsal view, showing how the wings overlap.

5. Fasten the squash bug's wings out at right angles to the body, and make another drawing, showing how the outer wings appear when extended, and how the inner wings are disposed.

6. Draw a ventral view.

Look for eggs. Compare young and old squash bugs. Squash bugs belong to the order **Hemiptera**, or half-winged insects. What is the propriety of this name? Insects belonging to this order are the only ones that are properly called "bugs."

Topics for Reports. — The Periodical Cicada. Plant lice. The Cochineal Insect. Scale Insects. The Chinch Bug.

THE BUTTERFLY.

The large brown monarch butterfly, or "milkweed butterfly," with dark markings along the veins of the wings, is a good one to study.

1. Notice the position of the eyes, and their relative size.

2. Where are the antennæ attached? Compare with those of the grasshopper.

3. The short projections in front of the head are the labial palps.

4. Between the palps is the coiled sucking tube; uncoil, and examine it.

5. The wings: —

(*a*) Their shape and their mode of overlapping.

(*b*) The dark, shiny veins; where are they strongest?

(*c*) Scrape some of the scales off a wing; examine under a high power of the microscope, making drawings.

(*d*) Examine with a low power of the microscope a piece of a wing, with the scales on it, to see how they are attached and arranged. Look at a part of the wing where the scales have been removed.

6. Spread the wings of a butterfly, and draw them as seen from above.

7. Examine the legs, and compare their use in this insect and others.

8. Make a drawing of the butterfly as seen when at rest, naming all the parts visible.

9. Compare the colors and markings of the upper and lower surfaces of the wings.

10. Carefully compare a moth and a butterfly.

11. Butterflies and moths belong to the order **Lepidoptera**, or scaly-winged insects.

The orders of insects are divided into **families**; this butterfly belongs to the family **Nymphalidæ**.

Families are divided into **genera**; this butterfly belongs to the genus **Anosia**.

Genera are divided into **species**; this species is **plexippus**. So this butterfly belongs to the class, Insecta; order, Lepidoptera; family, Nymphalidæ; genus, Anosia; species, plexippus.

The males are distinguished by an elevated black spot on one of the veins, near the middle of the hind wings.

Where is this butterfly found most abundantly?

Development of the Cabbage Butterfly.

The cabbage butterfly is small, yellowish beneath, paler above, with black tips to the anterior wings. The male has one round black spot only on each upper wing, while the female has two, and sometimes three.

1. Open the abdomen and look for eggs. They are yellow, oval bodies, ribbed lengthwise, with cross markings on the ridges, resembling stunted ears of yellow corn. Look also for these eggs on cabbage leaves, or where the butterflies are seen hovering. Watch the butterflies closely as they light on the cabbage leaves, to see the egg deposited on the leaf; on which side of the leaf are the eggs usually laid? How are they fastened to the leaf? Make a drawing of the egg as found attached to the leaf.

2. Get a chalk box with a sliding cover; substitute a glass cover a little longer than the box. Keep the box on end, so that the door will keep closed, yet may be easily opened. Put into this box a cabbage leaf with eggs on it; examine several times a day. What becomes of the egg? In another box, similarly arranged, put some large cabbage worms; give them fresh leaves every day, and keep the box in a light, well-ventilated room. Watch closely, and keep record of the date of the beginning of the experiment, and note the date of any change; describe carefully all actions and changes in the worms. Make careful drawings of each stage of growth: —

(*a*) The egg.

(*b*) The larva, at different stages of growth; keep one worm in a cage by itself, and make a drawing every third day.

(*c*) The pupa, showing how it is suspended.

(*d*) The perfect butterfly.

3. The cabbage butterfly belongs to the family Pieridæ, genus Pieris, species rapæ.

There are several species of the genus Pieris, just as there may be several persons in one family; as in a directory we read: "Smith, Charles," "Smith, Edmund"; so we read: Pieris rapæ, Pieris protodice.

What is the meaning of the word "rapæ"?

Occasionally a larva will fail to go through its proper changes; this is generally caused by some parasite, the most common of which is an ichneumon larva. The adult of some ichneumon fly lays it eggs on the body of the cabbage worm; these eggs hatch out as worms, bore into their host, and live on the juices and tissues of the cabbage worm, till it dies from exhaustion (though the cabbage worm often lingers, and the parasitic larvæ complete their transformation first), and the parasitic larvæ become pupæ, and hatch out as perfect ichneumon flies.

Look for holes in **pupæ** which fail to complete their transformation; often holes may be found in them where the ichneumon flies have made their escape. If a pupa blacker than usual be found, put it in a vial, or pill box, and catch the ichneumon flies as they emerge.

Topics for Reports. — The Clothes Moth. The Silkworm. The Tent Caterpillar. The Codling Moth. Cecropia. Polyphemus. Cutworms.

THE HOUSE FLY.

The Parts of the Body.

1. The **head**, the foremost, or anterior, part.
2. The **thorax**, or middle portion.
3. The **abdomen**, the hinder, or posterior, part.

The Head.

1. Examine the eye with a strong lens, and under a low power of the microscope, to discern its parts or facets. What shape have the facets?

2. Cut off the head, lay it on a glass slide, and with a one-inch objective examine the short antennæ in front of the head.

3. Look on the top of the head for simple eyes.

4. With a lens examine the under part of the head to see the tongue. How does it move? Remove it and look at it with a one-inch objective. How is the tongue used?

The Thorax.

1. How many legs are there? To what are they attached? How many segments has each leg?

2. The wings; how many are there? Back of each wing find a short membrane, the winglet. Note the folded portion connecting the wing and the winglet.

3. A little farther back are two slender stalks ending in rounded knobs; these are the **balancers**, and are considered as representing the hinder wings found in most insects. Note the effect of removing the balancers.

4. The wings describe a figure 8 in flying, and make over 300 vibrations (*i.e.* go up 300 times and down 300 times) in a second.

5. On each side of the thorax, just back of the head, find a narrow opening with a yellow, liplike border; examine closely with the aid of lens and microscope. It is a breathing pore, or spiracle.

The Abdomen.

Are there spiracles on the abdomen? How many rings has the abdomen? Draw the fly as seen from above (dorsal view).

The house fly lays its eggs about stables; after a day or two the egg hatches out as a maggot, which eats voraciously and grows rapidly; in about a week it ceases eating, becomes dry and brown, resembles a seed, and does not move; from this **puparium** the fly emerges. The adult fly is short-lived, tho some live over winter. Watch the development of the egg which the flesh fly lays on meat and dead animals. How many kinds of flies do you know? How do they differ? How does the fly walk on the

window pane? Examine the feet? In what order does the fly move its feet in walking? For the study of this point, take a fly that is sluggish from cold, or from partial drowning. Do flies, on the whole, injure man, or benefit him? Flies belong to the order **Diptera**, or two-winged insects. What other insects have but two wings?

Topics for Reports. — The Mosquito and Disease. House Flies. Horseflies. Botflies.

THE BEETLE.

1. What are the characters that appear peculiar at first sight?

2. Note the position and shape of the **eyes**.

3. The **antennæ**, their attachment, parts, and mode of extension.

4. A small upper lip, the **labrum**.

5. A pair of strong jaws, the **mandibles**, often very large, and projecting forward as pinchers, or "horns." How do they move?

6. Back of these are two small jaws, the **maxillæ**, bearing a pair of jointed appendages, the **maxillary palps**.

7. Back of (posterior to) the maxillary palps is another pair of similar appendages, the **labial palps**.

8. The part of the body back of the head is the **prothorax**. Why not call it the thorax?

9. Pry up the hard outer wings. How do they meet each other? Each outer wing is called a wing cover, or **elytrum**. In what direction does the beetle move the elytra in raising them? How are they held during flight? Do they rise vertically?

10. How are the inner wings folded? Compare the inner and outer wings in length and size. Cut a piece of paper of the same shape as the inner wing, and fold it as the inner wing is folded. How does the beetle perform the act of folding the inner wings? Capture live beetles and watch this process.

11. Make a drawing of the back, with the wings closed; another drawing, with the wings fully expanded, as in flight.

12. Count the segments of the legs. Examine each segment closely. Seize the foot of one of the hind legs with the forceps,

and pull it about in all directions, to see how many joints the leg has, and what motions are allowed by each joint. The segment nearest to the body is the **coxa**. Then come, in order, **trochanter, femur, tibia,** and **tarsus** (foot).

13. What marks the line of division between the thorax and abdomen?

14. Draw a ventral view on a large scale, showing especially the parts of the legs, and the mouth parts.

15. Watch a crawling beetle, to see in what order the legs are moved.

16. What can you tell of the habits of beetles? The different kinds of beetles, and their development? What is a grub? Compare beetles with other insects in strength. The large beetles are good insects for dissecting, to show the internal structure. Beetles belong to the order **Coleoptera**, or sheath-winged insects.

Topics for Reports. — Fireflies. Blister Beetles. The Carpet Beetle. Water Scavenger Beetles. Whirligig Beetles. Carrion Beetles.

THE BUMBLEBEE.

1. Find three simple eyes on the top of the head. How are they arranged?

2. Describe the antennæ.

3. The mouth parts: —

   a. A pair of true jaws.

   b. The long, hairy tongue.

   c. Above the tongue the two blades of the maxillæ.

   d. Below the tongue two thin, narrow labial palps.

The last three form a proboscis. Pick the parts asunder, and make a drawing of the front of the head, showing all these parts.

4. How does the bee take its food? Is the honey stored by the bee the same as the nectar taken from the flower?

5. Compare the segments of the legs with those of the grasshopper. How does the bee get pollen? What does the bee do with the pollen?

6. Examine the wings; compare the front and hind wings.

7. Get a bumblebees' nest; examine the contents of the cells, and note the different stages of development of the young bees.

8. The sting is a modified form of ovipositor. Near its base are poison glands, and a sac for storing the poison. Remove a sting with the poison sacs and examine under a low power of a microscope.

9. How do bees compare with other insects in intelligence?

10. Ants, bees, and wasps belong to the order **Hymenoptera**, or membrane-winged insects.

Topics for Reports. — Bumblebees. Wasps. Solitary bees. Ants.

STUDY OF THE DEVELOPMENT OF THE HONEY BEE.

Through the glass sides of the hive observe the comb. The depressions or holes in it are the cells. Find cells that are empty, others that are partially filled with a substance whose glassy surface reflects the light. These cells contain honey. Find cells apparently empty, but which upon close observation are found to have a small, oblong, white body at the bottom of them. These may be seen attached by one end to the bottom of the cell near its center. They are not as large as the head of a pin, and are often overlooked. They are eggs. Record the date upon a small piece of paper, and paste it on the glass opposite the cells containing eggs, and note the changes from day to day. Determine the number of days elapsing between the time the egg was laid and the time of hatching. Make several trials. Begin with empty cells, and note when the eggs are laid, as some of the eggs may have been in the cells a day or two before you found them. Determine the length of time the young bee is in the grub or larval stage. The larva may be seen one or two days after hatching, floating in a small drop of gray-colored liquid at the bottom of the cell. Note its rate of growth. What care has it received? Has it been nursed, fed, and cared for, or has it, like Topsy,

"jest growed"? Find other cells near the brood (by brood is meant young bees in all stages of development) which are partially filled with a yellowish or brownish pastelike mass. This is stored pollen, or "bee bread." Its color varies according to the kind of flowers from which it is gathered. Now look for larvæ in all stages of development, from the smallest, which are little larger than the egg from which they came, to those which almost fill the cells they occupy, and in which the segments may be easily counted. Find other cells each covered with a brown cap. Observe them closely from time to time, and try to determine what they contain. Cells near the ends and top of the brood frame, which are covered with white caps of wax, contain honey. The caps of the latter may appear dark if the honey touches the caps, but usually there is an air space between the honey and the caps, and the caps appear white. Look for both of these conditions. What changes have you noted through a period of ten or twelve days in the cells in which you first found eggs? Can you now see the interior of the cells? Can you discover the bees placing brown caps on cells containing the largest larvæ? If so, note the date and determine the length of time the caps remain on them. Determine how and by whom these caps are removed. Watch to see some of the occupants of these cells come out. Note any difference in appearance between these and older bees. If these directions have been followed through a period of several weeks, you have observed all of the stages of development of a honey bee, and noted the length of time the young bee was in each stage. Which of these stages corresponds to the caterpillar stage of a butterfly? Which to the cocoon stage of a moth?

Honey Bees at Work.

Watch the bees as they come and go at the entrance of the hive. Dust a little flour upon some that are entering, and note to what part of the comb they go. Determine, if you can, whether they remain in the hive for some time or soon leave it again. Look for bees coming in loaded with yellowish or brownish pellets attached

to the outside of the large segments of the hind legs. Where and how do they unload? What are they carrying? Why do they bring this substance? In the latter part of the season bees sometimes carry propolis, a sort of glue, in the manner above suggested. This latter substance is used to seal cracks and crevices. Observe that some of the bees on the comb move about from cell to cell, putting their heads into the cells where there are larvæ. What is the work of these bees? Are they young or old bees? What is pollen? What is nectar? How does honey differ from nectar? What is beeswax? Is it gathered by the bees, or do they make it? What difference in color between new honeycomb and the brood comb you have just been studying? Why this difference in color?

Study of the Structure of Honeycomb.

Obtain two pieces of empty honeycomb, one with cells the same size as those in the brood comb in the hive, and the other with cells somewhat larger. Note the shape of the cells. What geometrical figure is represented by a cross section of a cell? Why not have round or square cells instead of this form? Lay a foot rule upon a row of cells across the face of one of the pieces of comb. How many cells in one inch? Make several measurements to obtain an average number. The average diameter of the cells may be expressed by what common fraction? Repeat with the other piece of comb and compare results. For what especial purpose do the bees use each kind? Do they ever use both for the same purpose? Draw a face view of each kind of comb, being careful to show correctly the relation of each cell to the cells adjoining it. Cut a piece of comb so as to show a freshly exposed edge. Note the shape of the bottom of the cell and the relation of those on one side of the comb to those on the other. Draw an edge view of a piece of comb, using care to show this relation. Note the number of parts in the bottom of each cell. Shape of each part. Make a pinhole in each part of the bottom of a cell. Turn the comb over and find how many cells have holes in the

bottom. Why this number? What new fact in regard to the relation of the bottom of a cell to the cells on the opposite side of the comb? Why should the bottom of a cell be of this form and not flat? Why this relation to the cells on the other side?

THE ANT-LION.

Field Study of the Larva. — In dry, sandy places look for conical depressions, as evenly made as if rimmed out by a mechanic. Many of these pits may be found near each other, in the neighborhood of ants' nests. Drop a few grains of sand into the center of the pit, looking closely meanwhile, for the protruding jaws at the bottom of the pit.

Quickly scoop up the whole pit, aiming to go an inch deeper than its greatest depth. This can be done very well with the hand, though a garden trowel is best. A tin cup or dipper would serve very well. Sift the sand thus scooped up through the fingers or over the edge of the hand, and look closely for the dull gray larva of the ant-lion (Fig. 16). It has an oval body, and a pair of long, hooked jaws. Place the larva on sand held in the hand, cup, or can, and see how it buries itself.

Home Study of the Ant-lion Larva. — Take several larvæ home. Place each on sand in a separate tumbler or can. Two or three inches deep will be enough. Watch again how the larva buries itself. Watch patiently to find how it digs the pit. Drop an ant, a crippled fly, or almost any small insect into the pit and see what the larva does. How does it eat? How much of its victim does it consume? For the appearance of the adult ant-lion see Fig. 15, in the descriptive text.

REVIEW OF INSECTS.

Take any insect not yet studied, and examine it thoroughly. Write a full description, and make drawings of it. Which of the insects previously studied is this most like? To what order, then, does it probably belong?

Select two pages in your notebook that face each other. On the left-hand page make a list of characters common to all the insects you have studied, numbering the points; on the right-hand page write briefly the characters peculiar to each insect. The first list ought to be a very nearly correct definition of an insect, so far as external features are concerned. The second list should serve as a definition of each of the orders of insects.

All the orders of insects belong to the class **Insecta**.

Write now a list, in vertical series, of the orders of insects studied, with the name of the insect representing that order opposite it, and include all within a brace opposite the word **Insecta**.

Read *Insect Life*, Comstock.

CHAPTER IV.

ARACHNIDA AND MYRIAPODA.

STUDY OF LIVE SPIDERS.

Spiders and Spider Webs. — Find a spider at home near you, where you can conveniently watch it for some time each day. What is the shape of the web? Do all spiders make the same kind of a web? Does the same spider always make a web in the same way? How is the web situated? Does the spider stay on the web? If so, on what part of it? What reason for this position? If you cannot find a spider beginning a new web, destroy a web and watch to see if a new one is begun soon. Does the spider take the same place for the new web? How does it begin the work? Is every part kept as first made, or is any part comparable to the scaffolding erected by the carpenter? Do spiders repair broken places in webs? If so, how is this done? How is food secured? Watch the whole process of capturing and eating food. Does the capturing of the food injure the web? Are spiders equally active at all times? Visit a spider in the evening and see if it is awake, and "ready for business"? Are spiders affected by cold? Do they like sunshine? Do they live over winter? What can you learn about the development of spiders? Why are there sometimes so many spider webs floating in the air? What relation have these floating webs to the weather? Are these floating webs of any use to spiders? How are they set afloat, and what keeps them afloat? Can you discover the beginning of such work? How and where do spiders lay their eggs? Watch the development of the eggs.

External Features of the Spider.

Spiders are best preserved in alcohol, as they shrink in drying.

1. The anterior division of the body is the **cephalothorax**, or united head and thorax.

2. The large posterior division is the **abdomen**.

3. How many legs are there? To what are they attached? How many segments are there in each? Examine the feet under a microscope. Make a drawing of one of the feet. Can a spider climb out of a tumbler? Compare it with the beetle in this respect.

4. With a dissecting needle pry apart the mandibles, at the front of the head. The duct of the poison gland opens at the tip of each mandible.

5. Back of the mandibles find a pair of small jaws, the **maxillæ.**

6. To the maxillæ are attached a pair of jointed appendages, resembling a pair of legs, the **maxillary palps**.

7. With a lens look for the simple eyes above the jaws. How many are there, and how are they arranged?

8. With a lens examine the **spinnerets** at the posterior end of the abdomen. With a pair of forceps hold a live spider by one leg, and watch the beginning of spinning.

9. Besides air tubes, some spiders have one or two pairs of **lung sacs**, composed of several leaves, into which blood flows, and is thus aërated.

Place the description of the spider alongside the list of characters common to insects, and note what features are common to the spider and all the insects; also the points wherein they differ. Spiders belong to the class **Arachnida**.

Read Emerton's *Spiders, their Structure and Habits*.

MYRIAPODS.

One form of "thousand legs," commonly found under stones and under the bark of dead stumps and logs, is well known by its cylindrical body, by its numerous, short, hairlike feet, and by its

habit of coiling its body into a spiral when disturbed. This is a milliped.

1. How many segments has the body?

2. How many appendages has each segment?

3. Make a drawing of the thousand legs.

4. What are the chief differences between this animal and insects?

Another common form of thousand legs is that called centiped. It is, when full grown, about an inch long, with a broad, flat head, a brown, shiny back, the segments being generally about the same size, with one pair of jointed appendages to each segment. The antennæ are many-jointed. It is found under boards and about rubbish and manure heaps, where it feeds on insects and earthworms. It usually runs actively when uncovered.

1. Examine the jaws and mouth parts carefully; how many pairs of jaws are there?

2. With a lens examine the legs. How many are there?

3. What kind of eyes are there? How many, and how placed?

4. Arrange the legs so they can be distinctly seen, and make a drawing as seen from above.

5. Make an enlarged drawing of the mouth parts as seen from below.

6. What are the differences between this form and the thousand legs mentioned above?

7. In what are the two alike? Both belong to the class **Myriapoda.** Carefully compare them with the insects, and make a list of points common to insects and myriapods; also a list of the characters which insects have and the myriapods do not have; and a list of points peculiar to myriapods.

CHAPTER V.

CRUSTACEA.

STUDY OF THE LIVE CRAYFISH.

Field Study.

Where to find Crayfishes. — Look under stones in shallow creeks, under ledges of rock, or overhanging banks of streams. Remember that crayfishes are nocturnal and are usually hiding during the daytime. Note all the kinds of places in which you find them, and where they are most numerous. Are they in deep or shallow water? In clear water or muddy? In fresh water or foul? In quiet water or in rapid currents? Over mud, or gravel, or sand?

How they Escape. — In turning over stones or tin cans in a stream, note closely how the crayfish escapes. Which end goes foremost? What is the chief organ of locomotion? How is this used? How far does a frightened crayfish ordinarily go before stopping, if not closely pursued? Does it stir up mud in its flight? If so, how is this done? Does the stirring up of mud benefit the crayfish? If the crayfish goes some distance, is the rate of motion uniform? Explain.

Color of the Crayfish. — Note the color of the crayfish in relation to its surroundings, especially the color of the bottom over which it passes. Is its color an advantageous one? What if it had the color of a boiled crayfish? Are all crayfishes of the same color? How account for the difference?

Crayfish Holes. — Where are these most abundant? Do they all have "chimneys"? Is the chimney of the same color as the surface soil? How high are the chimneys? Are these built

during the day or during the night? How does the crayfish build the chimney? How deep are the holes? What are they for? Do all kinds of crayfishes dig holes? In what part of the hole does the crayfish stay? Are the holes used equally at all seasons?

Molted Shells. — If you find what appears to be a dead crayfish, examine it carefully to see whether it is really a dead animal or only the cast-off shell. Do you find any dead ones?

Enemies of the Crayfish. — Have you seen any animal eating or attacking a crayfish? Or any evidences of such action?

Home Observations.

Walking. — If one has no aquarium, a dish pan or homemade trough serves very well. Watch a crayfish crawling in the water. What appendages are used? Can it walk in other directions than head foremost? Are the legs moved in regular order? Place a crayfish on the floor. Does it walk equally well in water and out? Why should there be a difference?

Swimming. — Frighten a crayfish by thrusting a stick at it to see how it swims. Study closely the parts used and their action. Suppose a crayfish could propel itself rapidly forward, how would the resistance compare with the resistance it meets while going backward? Note closely the condition and position of the tail fin while making the stroke and while darting through the water between strokes. Observe all the points of structure that aid the efficiency of the stroke? What is true of the amount of resistance in the recover stroke? With the thumb and finger, take a crayfish just back of the big pinchers and hold it with the head up, so that the tail fin is covered with water; if it is now excited, the effectiveness of the tail fin will be well demonstrated.

Mode of Defense. — With a stick or pencil, make motions at a crayfish to see how it defends itself. Allow it to grasp a pencil to show the strength of its grip. Does a crayfish prefer to fight, or would it rather avoid an attack? In an aquarium does a crayfish

stay in open places, or where the light is strongest, or does it seek sheltered places?

Feeding. — Offer a crayfish various kinds of food, bread, meat, cheese, vegetables, etc. Find what it prefers. Learn how it eats, what organs are used and how they are used. Does a crayfish eat much or little? Is it a rapid or a slow eater? Examine the mouth parts in this connection. (In these experiments be careful not to let the water become foul.)

The Water Currents to the Gills. — While a crayfish is at rest in shallow water, carefully introduce a few drops of ink near the bases of the hinder legs. Where is it drawn in and where does it reappear? Try placing the ink at various points along the edge of the carapace. Place a crayfish in a candy jar. Watch it from the front and below to see the vibratory motions of the outer branches of the maxillipeds. Their motions indicate the rate of movement of the gill scoop, or gill paddle, within. Count the vibrations for a minute. How is it that a crayfish, while breathing by gills, can live so long out of water?

Senses. — Note the range of motion of the eyes. Can an enemy approach a crayfish from any direction without being seen? Can a crayfish see small objects as well as large ones? Does it notice slow motions as readily as quick ones? Does a crayfish see where it is going when it is frightened and darts backward by swimming?

What advantage is there in having the eyes on movable stalks? What disadvantages? In what ways is the eye protected? Touch one of the eyes. What follows?

With a straw, broom-straw, or feather, test the sense of touch over all the outside of the body. Where does the crayfish seem most sensitive to touch? Is there any special reason for having two pairs of "feelers"?

Which reach farther forward, the big claws or the antennæ? Can the antennæ extend back as far as the tip of the tail fin?

Make noises near the crayfish to test its sense of hearing. In

these experiments take care not to produce such vibrations of air, water, or mud as might effect the sense of touch.

Test the sense of smell by placing various odorous substances near the crayfish, when in air as well as in water. Is any attention paid to scents?

Recall any choice of food the crayfish has made? Is this choice determined by a sense of taste? Place various substances that affect your sense of taste on the crayfish's food. Does it make any difference in his choice? Place on the mouth organs drops of various liquids that affect your taste. Is the crayfish affected thereby?

Molting. — Sometimes when one has left a single crayfish in an aquarium he is surprised to find two. The molted shell looks like a complete crayfish. Watch a crayfish closely for this change. Before the molt a crayfish is dull and quiet. What are the first stages of the process, and in what order does he cast off the old shell? Feel of the newly emerged animal. For several days test the hardness of the shell. How long does it take for a "soft-shell" crayfish to become a "hard-shell"? What makes the shell hard? Drop a piece of the old shell in weak hydrochloric acid (vinegar will serve). Hold a piece of shell in flame. Does it burn?

Development. — Find a female crayfish with eggs. To what are the eggs attached? Watch till the eggs hatch out. How long are the little crayfishes when first hatched? Do they go free or remain attached to the mother? If they separate from her, do they return to her? Does she make effort to keep near them or keep them near her? Does she feed them? What do they eat at first? Do crayfishes ever eat each other? Do they kill each other?

External Parts of the Crayfish.

1. Note the two distinct parts of the body, (1) the anterior, rigid part, the **cephalothorax**; (2) the posterior, flexible part, the **abdomen**.

2. The covering of the cephalothorax is the **carapace**. Running across the carapace is the **cervical groove**. The anterior projection of the carapace is the **rostrum.**

3. Bend (flex) the abdomen, and straighten (extend) it repeatedly, observing how the segments are jointed together, and how they move one upon another. Count its rings or segments.

4. Separate the third ring (counting from the front) from the rings in front of and behind it. To do this hold the cephalothorax and fore part of the abdomen by the thumb and fore finger of the left hand, with the posterior end of the abdomen projecting toward the right hand; then, grasping the dissecting needle firmly with the right thumb and forefinger, thrust the point of a dissecting needle obliquely forward between the third and fourth segments, and work it up and down, severing all connection between them without breaking either; with scissors cut the membrane between the under sides of the rings, and entirely separate them. In like manner detach the third segment from the second. The ring has these parts:—

a. The upper part, the **tergum.**

b. The under part, the **sternum.**

c. The side piece, the **pleurum** (projecting downward).

d. Two appendages, the **swimmerets**. (See Fig. 46.)

5. Observe that each swimmeret has a main stalk, the **protopod,** and two branches, an outer, or **exopod,** and an inner, or **endopod;** examine these appendages thoroughly. Lay the ring on its front side, make the branches of the swimmerets diverge enough to appear distinct, and make a drawing of the whole ring as seen from behind.

Compare the other segments of the abdomen with the third.

In the male the appendages of the first and second rings are larger than those of the other segments and are specially modified. In the female the swimmerets of the first and second abdominal segments are smaller than the others. The abdomen of the female is wider than that of the male, probably for the purpose of protecting the eggs and young, which are attached to the swimmerets

6. Study carefully the structure and action of the **tail fin.** Its middle piece is the **telson,** underneath which is the external opening of the intestine, the anus.

Remove the telson, and without disturbing the side parts of the tail fin, separate the sixth abdominal ring from the fifth. Now carefully compare this (sixth) ring and its appendages with the third ring and its appendages.

7. Are the appendages of the thorax borne upon rings like those of the abdomen? If so, where are the rings? With forceps seize the base of one of the hindmost pair of walking legs, and move it backward and forward; are these borne on a distinct ring? Carefully clean the sternum between the other walking legs, and look closely for indications of rings.

8. With the forceps break away one side of the carapace, beginning at the lower edge. This lays bare the white, feathery **gills.** Cover the specimen with water in the dissecting pan to show the gills more clearly. Move the legs of this side back and forth, watching the gills.

9. Study now the hindmost of the walking, or thoracic, legs. Count its segments. Observe how the first segment is joined to the body. Flex the leg as far as possible, in every direction, noting the number of joints, and the motions allowed by each. With the forceps seize the squarish, basal segment of this leg, and pull off the leg.

10. Remove in like manner the legs in front of this, again being careful to get a firm hold of the short, wide segment next to the body. What is the relation between the leg and the gill nearest to it? Lay this leg on a paper in front of the one previously removed. In this way pull off all the legs of one side, from the hindmost to the foremost, laying them in order. Compare them all with the one first taken. In the legs bearing pinchers is there any real new part added, or is the pinching apparatus produced by some change in a part presented in all the legs? How do the legs which bear the big claws differ from the walking legs? Compare them, segment with segment.

11. Anterior to the big legs are several pairs of appendages surrounding the **mouth**. Probe between them to find the mouth. These mouth parts are numbered from the front, but on account of the way in which they overlap, it is easier to remove and study them in the reverse order.

12. The appendages just in front of the big claws are the hindmost of three pairs of jaw feet, or **maxillipeds**. Gently raise them to see how they cover the other mouth parts. Note that these maxillipeds, or foot jaws, have an inner branch (endopod), which meets the corresponding part of the opposite maxilliped, and an outer branch (exopod). Observe that both these branches are attached to one segment (protopod), next to the body. Seize this basal segment, and remove the whole maxilliped. Compare it with one of the swimmerets of the third ring of the abdomen. In the same way remove the second and first maxillipeds of this side, keeping them in order. Are there gills attached to the maxillipeds? Is there more than one gill on each leg? Are there other gills than those attached to the legs? Pick one of the gills to pieces under water to determine its structure. After removing the gills, look in this region for further traces of thoracic rings.

13. Anterior to the maxillipeds are two pairs of **maxillæ**. These are very thin, and lie close to each other, so that if great care be not taken, they are likely to be pulled off together. Investigate closely, and then, inserting the forceps well down, remove them, one at a time. Attached to the base of the hinder maxilla is a thin, double spoon-shaped structure, the **gill scoop**, or **gill paddle**. It lies in the front part of the cavity in which the gills are, the **gill chamber**. With the forceps move back and forth the second maxilla of the other side, to see how the gill scoop is thereby moved. The gill scoop, swinging back and forth, pushes the water out of the front end of the gill chamber. The water thus expelled is replaced by fresh water, which comes up under the lower edge of the carapace, about the bases of the legs; thus the gills are constantly bathed with water containing a fresh supply of oxygen.

14. The **mandibles** are short, hard, and toothed. Each mandible bears a jointed appendage, the mandibular **palp**, which curves around the anterior edge of the mandible in a groove. Move a mandible about to see how it is hinged.

15. Closely fitting against the posterior surface of each mandible is a thin, leaflike structure, the **metastoma**. The metastoma differs from the maxilla in pointing outward and in being undivided. Remove it and complete the series of mouth parts, — mandible, first maxilla, second maxilla, first maxilliped, second maxilliped, third maxilliped. Remove the corresponding appendages of the other side, lay them in a row facing those of the opposite side as before removal, but not now overlapping each other, and make a drawing of the series, naming them.

16. The long projections in front of the head are the **antennæ**. Seize one of them with the forceps, and pull about in all directions, to make out the large segment, at its base, under the head. On this basal segment find a small white cone, with a hole at its summit. This is the aperture of the kidney, or **green gland**. Remove the antenna, with the whole of this big segment at its base. What, probably, is the use of the bladelike branch of the antenna just under the eye? Compare the antenna and its branches with a swimmeret.

17. Above the antennæ are the **antennules**.

18. In the base of each antennule, just underneath the eye, is the **ear sac**.

19. With the forceps pull the eye about to see its range of motion. Pull it out by its stalk, and examine with lens and microscope its black tip, or **cornea**. Each distinct area is a **facet**, and the eye is compound.

20. After removing the cephalothoracic appendages, and the carapace, carefully clean and thoroly examine the framework of the cephalothorax, still looking for traces of thoracic rings.

21. The skeleton of a crayfish, like that of insects, is an external skeleton, or *exo-skeleton*. Compare it with the internal skeleton, or *endo-skeleton*, of vertebrates.

Crayfish Card.

Get a piece of stiff, smooth cardboard six inches by eight; select some dark color such as will make a good background for the crayfish. With pencil make three fine lines lengthwise, one in the middle, the others an inch from the middle. Make a cross at the center of the middle line. Now dot all three lines at intervals of half an inch, starting from the center.

Separate the parts of a crayfish as in previous study. For this the specimen should be slightly moist. If too dry, it will be brittle. If too wet, it will stain the card. If the work is interrupted, it is well to keep the parts on a damp paper or cloth, and covered so they will not be scattered. The parts of a crayfish are so compactly put together that it is impossible to see them all, while in their natural place. One object of this work is to make a permanent preparation with the parts separated enough to show them distinctly. The crayfish is supposed to be crawling along the middle line of the card, and to have become dismembered and strung out. The carapace is to be in the middle line, with its hinder edge half an inch from the center of the card. The abdominal rings are to follow this at intervals of half an inch. The appendages are to be arranged along the side lines at intervals of one half inch, with their bases at the side line, and extending at a suitable angle forward. To support the carapace and abdominal rings, make a cardboard bridge of the same material as the card. This bridge should be just high enough to reach the under surface of the arch of the carapace. The rings should be strung on this bridge, and both the rings and the carapace sewed to the bridge at the top, with a thread of such color as to be as inconspicuous as possible. The ends of the bridge should be sewed to the card, and the lower edges of both rings and carapace fastened so they will not slip about. All needle holes through the card must be made from above to avoid leaving a rough place. Determine where each hole is needed, and pierce from the upper surface of the card, whether the thread is to be passed through from above

or below. In fastening the appendages, first decide just where the part is to lie. Then, directly under the basal part, make a hole from the upper side. Then pass the thread through, from below, over the appendage, and down again through the same hole. The loop thus made will hold the appendage securely and be little noticed if the thread has a suitable color. In this way fasten each of the longer legs at three points. Leave the eyes attached to the carapace, but arrange all the other appendages, from the antennules to the last thoracic legs. Label the whole series on one side, placing the name below each appendage.

Dissection of the Crayfish.

1. Place the crayfish in the dissecting pan, dorsal surface up, and cover it with water. Place a double-pointed tack astride the narrow part of each of the first pair of thoracic legs just back of the big pinchers. By pressing strongly with the thumb the tack can be set firm enough to need no hammering. Now pull the body of the crayfish back taut and tack firmly through the telson.

2. Insert the point of one blade of the scissors under the hinder edge of the carapace, about an eighth of an inch to one side of the middle line. Cut forward to the groove which separates the head from the thorax. Break away the whole of the side of the carapace. Push the gills downward, and cut them off at their point of attachment. Observe the thin wall separating the cavity in which the gills were, the gill chamber, from the body cavity. Clear away the other side likewise.

3. With the forceps pick away the narrow remaining strip of the carapace, *carefully*, as the heart lies just under it. The **heart** is an oblong, whitish body. Look for small white tubes, **arteries**, running forward from it toward the head. How many are there? Be on the lookout for other arteries. With the forceps gently lift the hinder end of the heart; note its angularity. Look for holes in the dorsal surface of the heart; how many do you find? Look also for holes on the sides and on the ventral surface.

4. Under the heart, and projecting in front of it, are the reproductive organs: in the female, the **ovary**, in which the spherical eggs may be distinguished; in the male, the whitish **spermary** occupies a corresponding position. The ovary sends downward on each side a tube, the **oviduct**, or egg tube, to the first segment of the third thoracic leg, where it opens externally. The **spermary** has a much longer, coiled white tube, which opens on the first segment of the hindmost thoracic leg.

5. Carefully cut away the roof of the head. The space within the head is almost completely occupied by the **stomach**, a roundish sac, with a thin wall, in which is a hard framework. Gently scrape away the soft tissues around the stomach, and examine it closely. Observe the narrow **gullet** or **esophagus** leading from the mouth to the stomach.

6. Along the sides of the posterior end of the stomach and the anterior end of the intestine lie the large digestive glands. They are yellow or greenish in fresh, reddish in alcoholic, specimens. Pick one of these masses to pieces to learn its structure. Find the duct leading from each gland into the intestine.

7. Observe the white **muscles** which extend forward from the abdomen along each side of the body cavity.

8. Beginning at the front end of the abdomen, close to each side, cut with scissors through the roof of the abdomen to the telson. Seizing the forepart of this roof with the forceps, carefully lift it and turn it backward. A thir layer of white muscle may adhere to it, or may remain connected with the organs in the abdomen. This is made up of the muscles that straighten (extend) the abdomen. Pick them away carefully with the forceps.

9. Running lengthwise, in the middle line, is the **intestine**, a thin-walled tube, often of a dark color from its contents. Trace it back to the anus and forward to the stomach. Carefully remove the intestine.

10. A large mass of muscle remains. This is composed of the muscles that bend (flex) the abdomen. How do these flexor and extensor muscles compare in size? Why the difference?

11. Draw the point of a knife blade or dissecting needle along the middle line of this muscle, at the bottom of the groove in which the intestine lay. After a thin layer has been cut through, the whole muscle may be easily separated into two rolls the whole length of the abdomen. Roll these carefully aside, pushing equally right and left; otherwise the nerve cord may be injured. Find in the middle line of the floor of the abdomen a slender white **nerve cord**, with enlargements at intervals. How many of these enlargements, **ganglions**, are there in the abdomen? What relation do the ganglions have to the segments? Observe the branches, **nerves**, given off to the muscles on each side. Trace the nerve cord forward to the thorax, where it disappears in the hard framework of the floor of the thorax. Break away as much of this framework as is necessary to follow the cord to the head. Make out that the cord is double. How many ganglions are there in the thorax? Note the branches extending to the legs and other organs. From the large ganglion back of the gullet trace two branches forward, one on each side of the gullet, till they unite in a large ganglion above the gullet, thus forming the **esophageal collar.** From the ganglion above the gullet trace nerves to the eyes, antennæ, and antennules.

12. Cut open the stomach, wash it out with water, and look on its inner walls for teeth.

13. Below and in front of the stomach, find a pair of pale green bodies. These are the **kidneys** or "green glands." Remove the stomach and study the structure of the kidneys. Find where they open externally.

14. Study the joint in one of the big pinchers. Pick out the muscle from the end of the segment, and find the thin, tough white tendons. Seize these with the forceps and pull alternately, to see how the claw is shut and opened. Which is larger, the muscle that opens the claw, or the one that shuts it? Explain.

15. In what characters is the crayfish like the grasshopper? In what do these animals differ? Make a concise list of these points of likeness and difference.

16. Why should the name **Crustacea** be applied to such animals as the crayfish?

Read *The Crayfish*, Huxley.

Topics for Reports. — The Lobster Industry. Shrimps. Crabs. Hermit Crabs. Sea Spiders. Fiddler Crabs. Cocoanut Crabs.

THE SOW BUG.

Sow bugs are usually to be found under boards and stones, and in other damp places. Get the largest specimens for this study.

1. The first part is the head, or carapace.

2. Find and describe the eyes.

3. What are the peculiarities of the antennæ? How many?

4. The jaws and maxillæ are closely pressed together, forming a short, blunt projection under the head. The tip of this blunt proboscis is usually black. A longitudinal groove shows the line of union of the hinder maxillæ. By pinching the body of a live sow bug, the mouth is sometimes more clearly shown by the exudation of a liquid, as in the case of a grasshopper.

Where is the line of division between the head and thorax? Count the appendages which may be supposed to belong to the head; how many rings do these indicate?

5. The line of division between the thorax and abdomen is indicated by an abrupt change in the size of the segments. How many segments has the thorax? Compare the numbers of segments in thorax and abdomen with those of the crayfish.

6. How many segments are there in the abdomen?

7. How many pairs of legs are there? How many segments has each leg? Do the legs all extend in the same direction?

8. A series of thin, overlapping plates under the abdomen are the gills. In the anterior plates observe the white **air chambers.** Beginning at the foremost of these gills, pick them apart with a needle. Remove them, and with a lens make out their shape and arrangement.

9. Under the thorax of the female there is a series of thin membranes attached near the bases of the legs. These are the

egg covers. The eggs, after being expelled from the body, undergo their development in the space under the thorax inclosed by these egg-covers. Look for specimens carrying eggs in this manner.

10. In what respect are the sow bug and crayfish alike? In what respect do they differ from each other?

The crayfish and sow bug both belong to the **Crustacea**. The class Crustacea is divided into several orders. The order to which the crayfish belongs is the **Decapoda,** or ten-footed; the sow bug belongs to the order **Tetradecapoda,** or fourteen-footed.

CYCLOPS.

Along the sides of aquaria, and sometimes in drinking water, there may be seen minute white animals swimming with a jerky motion. Cyclops has a pear-shaped body, and is just large enough to be seen readily with the naked eye. The females carry two egg masses attached to the sides of the abdomen. With a lens, watch these animals through the side of the aquarium. Place a female cyclops with a few drops of water in a watch crystal, or a piece of glass. Examine under a three-legged lens, or under a low power of the microscope.

1. The foremost division of the body is the **carapace.**

How many segments has the thorax?

2. The **egg sacs** are attached to the first ring of the abdomen.
3. The **eye**; note its color, position, shape, and parts.
4. The **antennæ** and other appendages.
5. How does cyclops swim?

Make a careful drawing of cyclops as seen from above. Cyclops belongs to the subclass **Entomostraca** (water fleas).

CHAPTER VI.

ANNULATA.

FIELD STUDY OF EARTHWORMS.

1. In what kind of places does the fisherman dig for earthworms?

2. Are they more abundant in one kind of soil than another?

3. Look for the coiled excrement, or "castings," at the mouths of the holes. How many holes can you find in any square yard? Find the number in several square yards at different places in a rich meadow or pasture, and compute the number in an acre.

4. Do you find earthworms during the daytime? If so, in what conditions? Hunt for them at night with a lantern. Are they far from their burrows? Do they appear frightened? Do they retreat into their burrows?

5. If a worm is found partly extended from its burrow, seize and try to pull it out. Is it easy to do so? Why not?

6. Carefully dig up a number of earthworms. How deep is the burrow? And what is its course? In what part of the burrow is the earthworm? Does the depth at which the earthworm rests depend on the time of day? The condition of the soil? The weather? Is the worm always the same end up? Is the hole much wider than the worm? Could it turn around in the hole?

7. Do earthworms ever plug up the mouths of their burrows? If so, when and with what material? How is this work done?

8. Do you find evidence of what earthworms eat? Do they eat their food outside or in their burrows? Do they store food? Do they spend much or little time eating?

9. Having quietly approached an earthworm that is out, or partly out, of its burrow, suddenly make a loud noise. Does it

seem to hear? Fire a pistol or cracker; does it notice the noise? Stamp hard on the ground; does this affect the worm?

10. In what month are earthworms most active? When least active? Do earthworms hibernate? How early are they seen in spring? How late in the fall?

11. What enemies has the earthworm? Has it any means of defense? On what does it rely for protection?

12. Do you discover anything to prove that earthworms lay eggs? If so, when and where does this take place?

LABORATORY STUDY OF EARTHWORMS.

Get a box a foot deep and a foot or two square. Fill it with fine, rich, black soil and press it down firmly, leaving an inch or so of space above the soil. Keep the soil fairly moist. Earthworms may be kept alive through the winter in boxes, or flowerpots of soil, covered with sod and watered occasionally. The soil should be kept cool and moist, but not wet. Put some dead leaves just under the sod, and occasionally place cabbage leaves or lettuce leaves on the sod for them to feed on. The boxes or flowerpots may be kept in a greenhouse or in a cellar. Cover the box with a large plate of glass. It is well also to have glass windows at the sides and bottom.

1. Place two dozen live earthworms on the soil. Watch them as they burrow into the soil. Do the worms soon become settled, or are they restless? How soon do they reappear at the surface?

2. Test the worms with various kinds of food, meat, both lean and fat, bits of cabbage, celery, onion, turnip, apple, etc. Which do they prefer? Do they show evidence of a sense of taste? Of a sense of smell? Do they eat on the surface or in their burrows? Do they eat the material at once or keep it for a time? Do they eat little or much? Do they exercise choice in selecting bits of food according to their size or shape? When do they eat? Is the process slow or rapid? How is the eating done?

3. Place an earthworm in a glass tube with good black soil, and watch it from day to day.

4. Try the effect of sound on earthworms, being careful that they do not get vibrations that affect the sense of touch during the experiments.

5. Try the effects of light, being careful not to apply heat at the same time. Place the worm in a glass tube, and let the light fall upon one part at a time, covering the rest of the tube with a cylinder of black paper. Try also the effect of heat without light.

6. Repeat any experiments given under "Field Study" that may profitably be reviewed.

7. What is the appearance of the surface of the soil as a result of the work of earthworms? What effect do earthworms produce in the condition of the soil?

STUDY OF A LIVE EARTHWORM.

1. Place a live, active earthworm on a large sheet of paper and watch its behavior. Does it move with the same end always foremost? Touch the end that is foremost to see if it will reverse its motion. What changes take place in its body during locomotion? Can you explain how it progresses?

2. Take the earthworm in the fingers of one hand and draw it over a finger of the other hand to feel the bristles; of what use are they? Can you learn how they are arranged? Do they point more toward one end of the body than the other? Place the worm on glass; can it crawl as well as on paper? Why should the condition of the surface affect the worm's locomotion?

3. Touch various parts of the body to learn the degree of sensitiveness of different parts.

4. Turn the worm over on its back; does it remain in this position?

5. Take hold of the posterior end of the worm and drag it backward along the paper; listen for any sound thus produced. How explain this result?

6. Rap sharply on the table; does this affect the worm?

7. Place the worm on a wet surface, and after a while on a dry

surface; does it appear equally comfortable in both conditions? Try also the effect of heat and cold, dust, mud, water, etc.

8. Observe along the middle of the back a blood tube; watch its pulsations. Can you discover any other evidences of circulation of blood?

EXTERNAL FEATURES OF THE EARTHWORM.

1. The end that usually goes foremost is the **anterior** end; the other end is the **posterior** end. Are the two ends of the same color? The surface on which the earthworm ordinarily rests is the **ventral** surface; the surface usually uppermost is the **dorsal** surface. The earthworm has **right** and **left** sides, that correspond to each other; such an animal is **bilaterally symmetrical**.

2. The earthworm is segmented, or marked off into rings called segments. How many segments has your specimen? Are the segments all equal in width?

3. About one fourth or one fifth of the length from the head observe a place where the segments are less distinct, often enlarged and with a different color. This is the **girdle**, or clitellum. How many segments does it occupy? How many segments are anterior to it?

4. Is the worm exactly cylindrical, that is, is the cross section a circle?

5. At the anterior end find the mouth. Overhanging it is a sort of upper lip called the **prostomium**. At the posterior end find the anus. Is it circular?

6. Find the rows of bristles on the sides and ventral surface. How many rows are there and how many bristles in a segment?

7. On the ventral surface of about the fourteenth segment are the rather distinct openings of the **oviducts**, and on the fifteenth the openings of the sperm ducts. Between the ninth and tenth segments are the openings of a pair of sperm receptacles, and another pair open between the tenth and eleventh segments. The positions of these openings vary in different kinds of earthworms, and they are not always easily discovered.

DISSECTION OF THE EARTHWORM.

Material: dissecting pan, forceps, scissors that cut well at the point, dissecting needles, two dozen pins. Ribbon pins are best for this work. Dissect under an inch of water and renew if it becomes turbid.

1. Lay the specimen lengthwise on the board, stretch it, and pin firmly at each end, slanting the head of the pin away from the worm. Cut through the skin of the back near the posterior end, and continue the cut forward a little to one side of the middle line. With the forceps lift the edge of the cut and run the dissecting needle along under it to cut the partitions that hold the body wall down. Turn the edges of the body wall out and pin them down, slanting the pins at an angle of about thirty degrees so they will be out of the way.

2. As soon as the edges of the cut are separated the **intestine** is seen. It is cylindrical, nearly filling the body cavity. It is usually dark-colored from its contents.

3. Along the top of the intestine is the **dorsal blood tube.**

4. Observe now more closely the **partitions** which extend from the intestine to the body wall between adjacent segments. Compare the positions of the partitions with the external markings and bristles. Are there as many segments as indicated by the external appearance?

5. Continue the cut to the anterior end, being careful not to cut into the intestine, especially in the part anterior to the girdle. Pin well out, and free the intestine by drawing the dissecting needle along its sides to cut the partitions.

6. In the region of the tenth segment are several pairs of white bodies, the sperm sacs.

7. Alternating with these are several red masses. They are the **aortic arches**, which spring from the dorsal blood tube and arch around on each side to join the ventral blood tube beneath the digestive tube. In some earthworms each aortic arch has several enlargements, making it resemble a necklace. The enlargements

are sometimes called "hearts." In a recently killed specimen they may be seen pulsating.

8. In the first six segments is a wide portion of the digestive tube, the **pharynx**. It has threads of muscle connecting it with the body wall. The pharynx is used as a proboscis, being protruded from the mouth and everted.

9. The pharynx narrows behind into the **gullet**. This extends through several segments, but is hidden by the sperm sacs and the aortic arches. Clear these away.

10. In removing the sperm sacs there may be seen in the ninth and tenth segments two pairs of small, white, spherical bodies, the sperm receptacles. The still smaller ovaries may be found in the thirteenth segment.

11. Back of the spermaries are two enlargements of the digestive tube. The first is the **crop** and the second the **gizzard**.

12. From the gizzard to the posterior end of the body extends the **intestine**. Is it uniform in diameter? If not, where is it wider and where narrower?

13. Cautiously dissect away the intestine. Under it is the **ventral blood tube**. From it as well as from the other principal blood tubes there are smaller branches to supply all the tissues.

14. On the very floor of the body cavity, in the middle line, is the **nerve cord**, resembling a white thread. Trace it from behind forward. In each segment is an enlargement, or **ganglion**. From the ganglions proceed branches to supply the surrounding organs with nerve fibers.

15. Under the anterior end of the pharynx the nerve cord separates into two parts, one passing up on each side to enlarge into a ganglion. These two ganglions are the **cerebral ganglions,** or **brain**, and the ring of nerve cord around the pharynx is the **nerve ring** or **nerve collar**.

16. Attached to the ventral body wall, on each side of the digestive tube, are many small, threadlike, coiled bodies. Examination with a lens shows a pair of these in each segment. They are the **kidneys** or **nephridia**. Each is a tube thrown into loops

The kidneys open to the outside usually between the inner and outer rows of bristles, but sometimes above the lateral row of bristles. And each tube kidney begins as a funnel, which is in the segment in front of the one in which the loops of the kidney are found.

17. The outer layer of the skin is thin and easily peels off. This is the **cuticle,** and is noticeable on account of its pearly luster. The bulk of the body wall is composed of two layers of muscles, the outer of circular and the inner of longitudinal fibers, by means of which the worm moves.

18. In a freshly opened earthworm mount a drop of the milky liquid found in the body cavity and examine it under a one-sixth objective. The corpuscles should be distinctly seen.

CROSS SECTION OF AN EARTHWORM (MICROSCOPIC).

1. Examine cross sections under the microscope, with a low power, one-half or two-thirds inch objective. The body wall may be seen to consist of several layers. The intestine has an extension, the **typhlosole,** from its dorsal wall, occupying considerable of the space within, and adding much to the inner surface of the intestine.

2. Examine with a higher power, one-fourth or one-sixth inch objective. There are five layers of the body wall: (*a*) the thin **cuticle**; (*b*) a thicker layer of skin, the **hypodermis**, or **epidermis,** which produces the mucus which coats the outside of the worm; (*c*) the layer of **circular muscle fibers**; (*d*) a thicker layer of **longitudinal muscle fibers**; (*e*) a very thin layer of **peritoneal epithelium**.

3. The dorsal blood tube lies embedded in cells on the dorsal wall of the intestine. Under the intestine is the ventral blood tube. Still lower is the nerve cord, or ganglion, as the section may strike.

Read *The Formation of Vegetable Mold through the Action of Earthworms*, Darwin; or the chapters on the earthworm in *General Biology*, Sedgwick and Wilson.

Topics for Reports. — Varieties of Earthworms. Marine Worms. Leeches.

CHAPTER VII.

MOLLUSCA.

FIELD STUDY OF FRESH-WATER CLAM.

LOOK for clams in the shallow water of creeks and lakes. Note the natural position. How much of the shell is embedded? Is the shell open or shut? Can you see any openings by means of which the clam communicates with the water? Touch the clam and note any changes that take place. Quickly pull up the clam and note the extended foot. Watch clams to see if they move. Do they move with the same end always foremost? How does the foot point with reference to the direction of locomotion? Does a clam make a track? Can you tell by the track in which direction the clam traveled? Does the direction of travel have any relation to the current of the stream? Why do clams travel? If possible, make a series of observations to find out the rate of locomotion. Where are clams more abundant, on sandy or on muddy bottoms? How many kinds do you find? Do different kinds show preference as to soil? Has the color of clams any relation to the surroundings? Do you find any evidence that clams have enemies? Of what kinds? How are clams protected from enemies? What conditions are unfavorable to clams? Do they prefer deep or shallow water? Do they occur singly or in groups? Do different kinds occupy the same region?

AQUARIUM STUDY OF A LIVE CLAM.

If a good aquarium is not obtainable, a battery jar, a tub, or a large pail will serve. Put in three inches of sand and add enough water to stand three inches above the sand. Let this stand over night to allow the water to become clear.

Position of the Clam. — Drop several clams into the water and note carefully the place and position of each. Watch them as closely as possible to see if they change their place or position, and if so, learn how this is done.

Locomotion. — Watch clams that have established themselves in their natural position, to find out how they travel. Do they leave a track? If so, of what sort is it? Is the motion slow or rapid? Is it at a uniform rate, or irregular? Quickly pull up a clam that is moving and note the projecting foot. Place a clam close to the side of a glass aquarium; the foot may be protruded so close to the glass as to be seen. Why do clams travel? Can a clam crawl on a hard surface?

Water Currents. — Note that a clam, when established in a natural position and left undisturbed, has the shell slightly open. Near the upper edge of the more exposed end look for two elliptical holes; these are the **siphons**. Watch to see if there is any evidence of currents through these holes. Reduce the amount of water so that it is about half an inch deep over the siphons of a large clam. Look closely at the surface of the water over the siphons for evidence of water currents. Take a slender glass tube, dip one end in ink, place a finger over the upper end of the tube and lift out a little ink. Carefully introduce a drop of this above the siphon opening. The currents may also be revealed by a little mud, but care should be taken not to drop coarse mud or sand on the siphons. What happens when the margins of the siphons are touched? Pull up a clam that is in "full blast," watching closely the siphons. Describe what you observe.

Senses of the Clam. — Test in various ways the senses of the clam. Touch it lightly and heavily; jar the floor near the aquarium. Throw strong light (without heat) upon it. Try heat without light. Test for all the senses you think a clam may possess.

Protection of the Clam. — Note again the changes that take place when an active clam is taken from the water. Now try to open the shell with the hands alone. Why does the clam have such a

hard covering and the ability to shut it so tightly and remain shut so long?

EXTERNAL FEATURES OF THE CLAM SHELL.

If a live clam is used, place it on a plate, or in the dissecting pan.

1. Notice the two parts of the shell, — the **valves.**

2. The edge along which the shell opens is the **ventral margin.**

3. The edge by which the two valves join each other is the **dorsal margin,** or **hinge margin.**

4. The concentric lines parallel to the ventral margin are the **lines of growth.**

5. The raised point around which these lines center is the **beak,** or **umbo.** The umboes are nearer the front, or anterior, end of the clam.

6. Toward the posterior end, back of the umboes, between the valves, and uniting them, is the **hinge ligament.**

7. Hold the closed shell with the hinge margin uppermost, the hinge ligament nearer, and the umboes pointing away from you.

The end pointing from you is the **anterior** end.

The end pointing toward you is the **posterior** end.

The upper edge is the **dorsal** margin.

The lower edge is the **ventral** margin.

The half-shell to your right is the **right** valve.

The half-shell to your left is the **left** valve.

Fix these relations firmly in mind.

8. Make a drawing of the clam as seen from the left side, naming all the parts.

9. Observe the color, the degree of cleanness, and general condition of the different parts of the shell, and consider the relations between these facts and the position of the clam when first found.

DISSECTION OF THE CLAM.

How to open a Clam. — It is difficult for beginners to open clams without mutilating the soft parts. It is better to have them opened by the teacher. If any student is following these direc-

tions without the aid of a teacher, he will find directions for opening clams, without using hot water, in the *Suggestions to the Teacher of Zoölogy*, in a separate pamphlet.

Put the live clam for a few minutes into water as warm as the hand can well bear. This causes the muscles to relax, so that the shell can be readily opened. Pry apart the two valves, and insert a half-inch block to keep them from shutting.

1. Observe a soft white membrane, the **mantle**, adhering to the inner surface of the shell. Look in at the posterior end for the two siphon openings. Now hold the clam in the left hand, with the left valve up and the ventral margin toward you. Insert the chisel-like handle or the blade of a scalpel between the mantle and the left valve, and gently separate them by sliding the scalpel handle along the inner surface of the shell. In this way proceed backward, around the posterior end of the shell, then forward along the dorsal margin. Back of and below the hinge is a large white muscle, which extends directly across from valve to valve. Cut this off close to the left valve if it is not already severed. In like manner loosen the mantle at the anterior end, and find another muscle connecting the two valves near the anterior dorsal margin. Sever as before, close to the left valve, and loosen the mantle completely from the left valve.

2. Press the shell shut; now release the pressure. What makes the shell spring open? Repeat the closing and releasing until you have a satisfactory explanation of the method of opening. Be on the lookout later for the means by which the clam shuts its shell. Break off the left valve by bending it forth and back, twisting it off if necessary.

3. Lay the clam in the dissecting pan and cover it with water. Renew the water as often as it becomes turbid. To keep the clam level use the left valve, hollow side down.

Observe that the left mantle lobe now covers the body, and that the right lobe lines the right valve. Notice the thicker margin of the mantle. Pinch this thick edge; if it has not already shortened as much as possible it may draw up slightly. Observe a thin,

dark-colored membrane bordering the edge of the shell. This is the periostracum, an extension of the outer covering of the shell. Scrape off some of it to see its relation to the limy shell. Carefully study the relations of the periostracum to the mantle. Pinch the edge of the right mantle lobe, and observe the effect on this free border. Trace the right and left mantle lobes to their points of union before and behind.

4. Examine the thick, dark-colored, hinder edge of the mantle lobes, and see how by their manner of meeting they form the two short tubes, the **siphons.** Prove the great sensitiveness of the margins of these siphon tubes. Are the margins of the two openings alike?

5. Examine the ends of the **anterior** and **posterior adductor muscles** where they were cut off in opening the shell; scrape away any part of these muscles that may remain attached to the left valve, and note the marks or **muscle scars** which are shown.

6. Turn the mantle lobe back as far as it will go, and observe the soft central **body**; its tough lower border is the **foot**; prick it with the dissecting needle, and observe what follows.

7. Along each side of the body and extending back of it are two thin membranes, the **gills**, showing vertical parallel markings. Study closely the relations of the gills to each other, to the body, and to the mantle.

8. With a knife scrape off a little of the surface of the gill and examine under the microscope to see the vibratory motion of the hairlike projections, or **cilia**, borne on the cells thus obtained.

9. In front of the gills, on each side of the body, are two thin triangular flaps, much smaller than the gills, the **labial palps**.

10. Raise the hind border of the left mantle lobe, and observe that the gill next to the body unites with the corresponding gill of the other side, thus forming a separate channel above the gills, from which the upper siphon leads, while the lower siphon leads to the lower cavity, outside of and below the gills.

11. With the thumb and all the fingers of the left hand seize the left lobe of the mantle and pull it toward the ventral margin,

thus drawing the body away from the dorsal margin. Just under the hinge a pale organ may be seen, pulsating every few seconds; this is the **heart.**

12. Holding the mantle stretched, again examine the upper siphonal opening; probe to see how it extends forward above the united hinder portion of the gills. In the upper part of this cavity find a tube running back over the posterior adductor muscle, and ending in a conical elevation; this tube is the intestine, and the opening at its end is the anus; hence the siphon leading from this cavity is called the **anal siphon**; the lower siphon, which conducts water to the gills and mouth, is called the **branchial siphon** or **gill siphon.** Examine the gills from above, *i.e.* examine their dorsal margins; observe that the two outer walls of each gill are a short distance apart at this edge, while below these walls unite, so that if the gill be cut across, these walls, as seen at the cut, are like the letter **V**. These diverging walls are connected by cross partitions, thus forming a series of compartments within the gill, whereas if these partitions were absent, each gill would be a deep, narrow, undivided trough. The lateral walls of the gills are sievelike, and the surface of the gill and the edges of the holes are covered with cilia. The vibrations of these cilia drive the water which is around the gill through these holes into the cavities within the gill; the water from each compartment of the gill passes up into the chamber leading to the anal siphon.

13. Beginning at the upper edge of the anal siphon, in the middle line, cut carefully forward just above the intestine as far as the umbo. This lays bare the cavity in which the heart lies, the **pericardial cavity.** Carefully cut away the thin covering of this cavity and make out the following parts of the heart: —

a. The large yellowish **ventricle** in the anterior part of the cavity; time its pulsations; observe that the intestine runs directly through the ventricle, though it has no communication with it. An artery runs forward from the ventricle along the upper surface of the intestine; another artery runs from the ventricle backward under the intestine. Again pull the mantle ventralward to show *b.*

b. A thin sac, triangular as seen from the side, with its apex joining the ventricle, and its base attached just above the upper edge of the gills; this is the left **auricle.** Each auricle receives the blood from the gills of the corresponding side.

14. Just in front of the posterior adductor muscle are the dark **kidneys.**

15. Above the kidney, and in front of the posterior adductor, is a small muscle, which extends backward from the side of the body to join the valve near the posterior adductor. This muscle pulls the foot upward and backward, hence is called the **posterior retractor muscle.**

16. Below and a little back of the anterior adductor muscle, find the **protractor muscle**, which pulls the body and foot forward.

17. Just above and back of the anterior adductor is the **anterior retractor muscle**, which pulls the foot and body up and backward.

18. To find the **mouth**, hold the clam, anterior end uppermost, still attached to the right valve; press down the point of the foot, and find the mouth opening posterior to the anterior adductor; observe that the two outer palps unite above the mouth, and the two inner palps unite below the mouth. Back of the anterior adductor a dark-colored mass may be seen within the body; this is the **digestive gland**, which surrounds the stomach. The intestine has several coils in the body before emerging on the dorsal surface a short distance in front of the heart. The intestine can be traced much better in an alcoholic specimen.

19. Beginning at the posterior adductor, cut away all the free flap of the left mantle lobe, following the upper edge of the gills (being careful not to cut away the labial palps) to the upper edge of the anterior adductor. Make a drawing of all the parts above named, as they lie in the right valve.

20. Remove all the remaining soft parts except the adductor muscles. Since the chief characteristic of muscle is its ability to shorten, it should now be clear how the clam shuts its shell. Turn back to No. 2 of these directions and consider the relations of the mechanisms for opening and shutting. What actions take place

during the closing? What actions during opening? Thoroughly clean the inside of the shell, and keep it for further study.

DEVELOPMENT OF THE CLAM.

Occasionally a clam may be found with the outer gills greatly thickened. Cut into such a gill and remove some of the contents. Place a little of the material on a slide and spread it out in a drop of water. Examine with a low power of the microscope. The parts of the young clams should be seen. How does the shape of the shell compare with that of the adult?

THE NERVOUS SYSTEM OF THE CLAM.

This dissection requires the utmost care and patience. Take a clam that has been hardened in alcohol, or by boiling. Dissect under water; rinse the specimen often.

1. Immediately under the posterior adductor muscle find a double yellowish body; this is composed of the two **visceral ganglions**; dissect away the thin membrane covering them.

2. From these ganglions trace nerves backward to the gills and to the posterior borders of the mantle lobes; trace also two nerves forward, carefully dissecting away the soft parts that cover them anteriorly, and trace them to the sides of the mouth where they join 3.

3. The **cerebral ganglions**; these lie near the surface at the bases of the **labial palps.** Trace a small nerve which connects the two cerebral ganglions over the mouth.

4. From each cerebral ganglion trace nerves backward and downward to 5.

5. A pair of orange-colored **pedal ganglions,** lying together deeply embedded between the foot and the body.

In the alcoholic specimen the stomach and intestine may be traced. Cross sections of alcoholic specimens may be made with a razor, which show admirably the relations of the different parts of the clam.

THE INSIDE OF THE CLAM SHELL.

1. Observe the color of the lining layer. Is it uniform? How would you describe the surface finish.

2. The **hinge teeth.** These are of two sorts: (1) the **cardinal teeth**, blunt, toothlike projections near the umbo; (2) the **lateral teeth**, long, ridgelike projections below the hinge ligament. Note how many of each of these kinds there are in each valve. How do they fit into each other? What is their use? Do you find them in all clam shells?

3. The **muscle scars**: (1) the **anterior adductor muscle scar**, near the anterior dorsal margin; (2) the **posterior adductor muscle scar**, near the posterior dorsal margin; (3) the **anterior retractor muscle scar**, just above and back of the anterior adductor scar, not very distinct; (4) the **posterior retractor muscle scar**, just above and in front of the posterior adductor scar; (5) the **protractor muscle scar**, just below and back of the anterior adductor scar; (6) the **mantle line**, running parallel to the ventral margin, from the anterior adductor to the posterior adductor scar.

4. The movements of the muscle scars. When the clam was smaller than it now is, where were the adductor muscle scars? Can you see any traces of the positions of these muscles at an earlier stage of life? Is there an evidence of growth over any part of the muscle scars that now show? Does the mantle line shift its position with growth?

5. The **ligament.** Examine the hinge ligament where it was broken off. Has it a definite structure? What is its chief characteristic?

6. Take an empty shell with the valves still hinged together; cut and fit into this a piece of paper showing the shape of the whole mantle.

7. Make a plaster of Paris cast of the inside of a whole shell.

8. Make a drawing of the inside of the right valve, labeling all the features above noted.

Take a large flat shell and label (with ink) both the external

and the internal features; it may be found convenient to label part of the features in one valve and part in the other.

Structure of the Clam Shell. — For this work get the thickest and heaviest shells, at least one valve for each member of the class. Weigh them and then roast them by laying them on an old shovel or layer of sheet iron, and placing them on the coals in a stove or furnace. After roasting handle them carefully so as to keep them entire. Weigh them again after roasting and compare with the former weight.

Hold a roasted valve by the dorsal margin in the left hand, with the inside of the valve toward you. With the fingers of the right hand supporting the outside of the valve, press with the thumb on the ventral border of the valve, outside of the mantle line. The shell should separate into two parts, the inner beginning very thin at the mantle line and becoming thicker toward the umbo; the outer portion extending the whole width of the valve, but becoming thicker from the umbo to the mantle line and thinner again from this line to the ventral margin. It will be seen that the plane of division is the plane along which the mantle line has traveled during the growth of the shell. Break a burnt shell across from the umbo to the ventral margin, and make a drawing of the edge thus exposed, showing the arrangement of these sets of layers.

Composition of the Clam Shell. — Put pieces of the burnt shell into dilute hydrochloric acid. The acid decomposes the limy compound, setting free carbon dioxid. If a fresh shell is placed in acid, the mineral matter will be slowly dissolved, leaving the flexible animal matter, which is called **conchiolin**. The hinge ligament is nearly pure conchiolon, being simply a part of the shell in which no limy matter has been deposited. When the shell is burned the animal matter is burned. The remainder after roasting is of about the same composition as lime. Put into acid a piece of the ligament. Does it contain lime? Place an entire valve of a thin-shelled clam in acid for forty-eight hours; what remains? Are shells ever found in rocks?

Topics for Reports. — The Oyster Industry. The Pearl Fisheries. Pearls from Fresh-water Clams. Kitchen Middens. Clambakes. Wampum. Tridacna. Mother-of-pearl. Pearl Button Factories. The Chambered Nautilus. The Paper Nautilus. The Giant Squid. The Octopus. Snails as Food.

THE POND SNAIL.

A dipper with a perforated bottom, attached to a wooden handle, will be found convenient in scooping up the sand and mud from the bottoms of ditches and streams; the dirt being washed out, the shells and other objects will be left behind. Get a number of live snails, and keep them in a fruit jar.

1. The broad disk on which the snail creeps is the **foot.**

2. The "horns" are the feelers, or **tentacles**; touch them; what would seem to be their use?

3. The dark spots at the bases of the tentacles are the **eyes**; are they borne on a stalk in any common snails?

4. Watch the snail crawling on the glass; near the front of the foot the **mouth** may be seen; observe its opening and shutting as the snail gathers food from the surface of the glass. Do snails clean the glass or foul it? Most snails have a ribbonlike tongue, fastened at each end, and covered with teeth; as this tongue is applied to an object, and drawn rapidly back and forth, it acts like a rasp.

5. Watch the snails, to see if any of them come to the surface to get air; how is this done?

6. Collect also land snails and river snails. Keep them and watch them to learn their structure and habits.

THE SNAIL SHELL.

1. The pointed end is the **apex.**
2. The opening at the large end is the **aperture.**
3. The outer edge of the aperture is the **lip.**
4. The lines parallel to the lip are the **lines of growth.**
5. The spiral groove on the outside is the **suture.**

6. The turns of the shell between the groove are the **whorls.**

7. The whorls, taken together, make the **spire.**

8. The lid closing the aperture is the **operculum** ; is this present in all the snails you find?

9. Lay the snail shell beside a common screw; if the whorls turn like the threads of the screw, it is a **right-hand,** or **dextral, shell,** if they turn the other way, it is a **left-hand,** or **sinistral, shell.**

10. Make a drawing, naming all the parts, of the snail shell with the aperture toward you; with the aperture away from you; with the apex toward you.

Read *The Chambered Nautilus,* Holmes.

CHAPTER VIII.

PISCES.

FIELD STUDY OF FISHES.

Difficulties. — In order to study fishes in their own homes with any degree of success, the student should know what are some of the main difficulties. First, a difficulty that is found in studying any wild animals, their shyness. The student must learn to approach them carefully. Second, the colors of fishes, as of many other animals, is such as to render them very hard to see. Third, the difficulty in seeing them is increased by the refraction of light leaving the water to enter the air, and also by the reflection of light from the surface, which greatly interferes with seeing what is below. This is especially noticeable in trying to see fishes from a boat, in which case the angle is quite oblique. Having in mind these difficulties and the determination to overcome them so far as possible, let us proceed to study the fishes in their homes.

Frightening Fishes. — When a fish darts away at your approach, endeavor to learn by what sense he first became aware of your presence. Was it by sight? If so, what can you do to overcome the trouble? Is it the color of your clothing, or of your boat? Is any given color, or group of colors, preferred for fishing boats? Which will frighten more, oars or a paddle? Should the paddle be lifted from the water, or used wholly in the water by making the recover stroke with the edge of the blade cutting thru the water? What part does the sunlight play in the use of oar or paddle? Does quickness of motion make any difference, the range of motion being the same? In using an anchor, which is better, a rope or a chain? Which is to be preferred, a wooden or a metal boat? Do fishes hear one who talks in a boat? Do sounds made by hitting the

boat, as with the heel, communicate with the water? Is it well to have bright metal, such as nickel or silver, on fishing rods?

The Water Glass. — The difficulties of seeing into water may, to a considerable extent, be overcome by the use of a water glass. This is a box or cylinder with a glass bottom. When the glass bottom is pushed down into the water, the face over the open end shuts out most of the light from above, thus getting rid of the confusion from reflection. It is possible to make such a glass as part of the boat, so one can view what is under the boat.

Food of Fishes. — Find what the fish you are studying prefers to eat. If you are fishing, examine the stomach of the first fish you catch to see what it has been eating. The wise fisherman will do his best to cater to the taste of the fish he would catch. Why does the fly-fisher drag the fly on the water, or make it dance about? Find the time of day at which a fish prefers to eat. Does this vary with any discoverable conditions? Do fishes eat during the night? What do the various artificial baits imitate?

Hiding Places. — What sort of places do fish hide in? Do they hide to escape enemies, or that they may catch unsuspecting prey that passes by their lurking place? In what situations does the fisherman look for different kinds of fishes?

Sociability. — What fishes live a solitary life? What kinds go in schools? What advantages in community life? What disadvantages? Does a school of fish scatter when frightened? Do they come together again soon?

Position in a Current. — When in a current do fishes maintain any fixed relation to the current, that is, do they rest crosswise, or lengthwise, in the stream? If lengthwise, is the head up or down stream? Why this position?

Egg Laying. — At what season does the fish you are studying lay its eggs? Are they usually deposited in the same surroundings? How long time is taken in depositing them? Are they guarded? What animals may destroy them? What conditions are favorable

or unfavorable to their development? If possible, learn the rate of growth of fish.

Fish in Winter. — Do fishes migrate? Are most fishes to be found in the same place, winter and summer? Are they equally active at different seasons?

AQUARIUM STUDY OF FISHES.

Respiratory Movements. — Watch minnows or goldfish in an aquarium. Note the movements of the mouth and the gill covers. In what order do these movements proceed? Watch closely to see if there is any water current in connection with these movements. If there is no floating matter by which to get evidence of a current, introduce a drop of ink near the fish's head and thus determine the direction of the current.

Mode of Swimming. — How does the fish swim? Watch especially the slow movements, during which the facts can be more readily learned. What is the main propelling power? How is the course guided? How is the shape adapted for movement in the water?

Uses of the Fins. — Take a light rubber band and pass it round the fish, holding down the various fins in successive experiments. Watch the resulting movements and conditions of the fish.

How a Fish Floats. — Does a fish make effort to maintain its place in water? Does it make any apparent effort in rising or sinking? Do any fishes habitually remain on the bottom? Do any stay at the surface? Is there any difference in their structure or habits that fits each for its place?

Comparison of a Minnow and a Darter. — These two forms are to be found in most creeks. In using a minnow seine, be careful to "keep the lead line down" and you will be much more likely to get darters. These are small fishes, with double-cone-shaped bodies. They habitually rest on the bottom. Watch carefully their movements. What takes place when they cease to make active effort? Do they swim in the same way as the minnows? Open a minnow and also a darter to see if there is any essential difference

in the structure of the two. Why should the darters have this habit of staying on the bottom?

Senses of Fishes.—Watch the movements of the eyes of a fish. What range of movement have they? Do the eyes move simultaneously? Does a fish see any better than you do? Devise means of testing the sense of hearing without affecting the other senses. Test the different senses in various ways. On which senses does the fish most rely for safety?

Food and Mode of Eating.—Offer a fish various kinds of food and find what it likes best. How does it take its food? What relation has the shape or size of the mouth to the kind of food taken? Does a fish eat much, or little, relatively? In feeding fishes take care not to give too much at one time, for fear of fouling the water. Do fishes suffer from overeating?

Sleep.—Do fishes sleep? Have they any special resting place or resting position?

EXTERNAL FEATURES OF A FISH.

For this work, and the dissection that follows, the perch is preferable for inland students, though the bass, croppie, or sunfish serves very well. On the seacoast the cunner or the sea perch is more accessible.

Lay the fish on a sheet of thick paper, on a plate, or in the dissecting pan.

1. Notice the shape of the fish as a whole; how is it adapted for motion through the water? Hold the fish with the back uppermost and the head directly away from you; instead of speaking of the front and hind ends, it is better to call them the **anterior** and **posterior ends.** The upper surface, or back, is the **dorsal surface,** and the lower the **ventral surface.** The **right** and **left** sides are counterparts of each other; that is, the fish is **bilaterally symmetrical.**

The perch is flattened from side to side, and is therefore said to be **compressed.** A fish is properly described as "flat" only when flattened on the dorsal and ventral surfaces, or **depressed,** as in the **case of the rays.**

In the following directions, relative and not absolute measurements are intended. Instead of using a foot rule, take a strip of paper and mark the entire length, head, depth, etc., either by pencil or by folding. Compare these so as to be able to say whether the head is one third, one fourth, or what part, of the length of the body.

Close the mouth of the fish, and measure from the foremost point of the head, the tip of the **snout**, to the front edge, the **base**, of the tail fin; this is the **length** of the fish. Measure from the tip of the snout to the hinder point of the hard part of the flap which covers the side of the head; this is the length of the **head**. How many times is the length of the head contained in the length of the fish? Measure from above downward at the deepest part; this is the **depth** of the fish. How many times is it contained in the length? Compare the **width** and the depth of the fish.

2. The fins on the back are the **dorsal fins**; spread them out to their fullest extent, and study them thoroughly; their framework consists of **fin rays**, some of them **spinous rays**, or **spines** (unjointed, or **inarticulated**), others **soft rays** (jointed, or **articulated**). Study carefully one of the soft rays, using a lens; spread the fin and hold it between you and the light to see the joints, which appear as fine cross lines on the soft rays; count each kind of rays; observe the membrane connecting the rays. This membrane is double; the fin is really a fold of the skin, with supporting parts within the fold.

Measure along the base of each fin; this is the **length** of the fin; extend the fin fully, and measure the length of its longest ray; this is the **hight** of the fin. Compare the length and the hight of the fin. In some fishes the dorsal fin is single; in others it is divided, forming two or more dorsal fins.

The tail fin is the **caudal fin**; is it symmetrical? The fin in front of and below the caudal is the **anal**; compare this fin with the dorsal. The fins above named, being in the middle line, are called **median, or vertical, fins.**

The remaining fins are called **paired fins**; the pair back of the head are the **pectoral fins**, and are considered as representing the fore limbs of the higher animals; the lower pair (usually farther back) are the **pelvic fins**, representing the hind limbs of higher animals. Take the pelvic fins between the thumb and finger to feel their bony support; rest the fish on its back, and press the thumb and forefinger of the other hand on the bony structures at the bases of the pectoral fins; move the pelvic fins about to determine, as far as possible by feeling, the relations between the bones supporting the two pairs of fins.

3. Open the mouth of the fish by pulling its lower jaw down as far as possible; the bone which forms the border of each side of the upper lip is the **premaxillary**; note its extension backward on the middle of the snout; observe the fine teeth on it. Observe their size, shape, arrangement, and the direction in which they point. The paddlelike bone back of the premaxillary, outside of the mouth, is the **maxillary**. The bone on each side of the lower jaw is the **dentary**.

Which of the above-named bones bear teeth? Open and shut the mouth repeatedly, watching the movements of these parts, and their relations to each other.

Back of the premaxillary, in the front part of the roof of the mouth, is a patch of teeth, borne on a bone called the **vomer**; extending backward from the vomer, on each side of the roof of the mouth, are rows of teeth on the **palatine bones**.

Examine the short **tongue**; feel its surface with the tip of the finger, or scrape it with the head of a pin; examine also the whole of the inside of the mouth, to see if there are more teeth than those mentioned.

4. Note the shape and position of the eyes; with the handle of the forceps press on the eye at various points near its margin, to see its range of motion; watch the roof of the mouth while pressing the eye, also press outward on that part of the roof of the mouth nearest to the eye. Compare the eyes with human eyes. Are eyelids present? Observe a thin bone embedded in the skin

immediately in front of the eyes; it is the **anteorbital bone.** This and several smaller bones just under the eye are known as **sub-orbital bones.**

5. Examine the **nostrils** in front of the eyes. How many are there? Probe them with a bristle tipped with sealing wax, or with the head (never the point) of a small pin; do they open into the mouth? Do any of them communicate with each other?

6. The flap at the side of the head is the gill cover, and the opening back of it is the **gill opening.** The upper, hinder piece of the gill cover is the **opercle**; along its lower posterior border, and rather closely attached to it, is the **subopercle**; in front of the opercle, and below and back of the eye, bordering the part known as the **cheek,** is the **preopercle.** If the margin of this be toothed, it is said to be **serrate**; under the preopercle, and in front of the lower end of the subopercle, is the **interopercle.**

The thin membrane below the gill cover is the **branchiostegal membrane**; the curved bones supporting it are the **branchiostegal rays**; count them. The narrow part of the body between the branchiostegal membranes is the **isthmus.**

7. Raise the gill cover and examine the **gills**; each gill has a central bony **arch**; on the hind and outer border of this arch is a fringe of red **gill filaments**; on the front and inner border of the arch are the teethlike **gill rakers.** Are these alike on all the gills? A red streak along the arch, at the base of the filaments, is made by the blood tubes, which bring the blood to and carry it away from them.

Thrust a finger into the mouth, and depress the tongue. What effect has this on the gills? What effect on the gill rakers? The slits between the gills, which allow communication from the mouth to the gill openings, are the **gill clefts.** How many gills are there? How many gill clefts? After this study of the gills in their natural position, remove the foremost gill, severing it at its upper and lower ends, and note more fully the parts above named, especially the structure and arrangement of the gill filaments and gill rakers; tear away some of the filaments, and find the groove

along the posterior, outer border of the bony arch in which run the blood tubes. Look on the inside of the gill cover for a red spot, the **false gill**.

8. Observe the arrangement of the scales. Pull out a scale and study its shape and the radiating and concentric markings. Compare its inner and outer surfaces, its anterior and posterior margins; make a drawing of it, naming its parts; pull out a scale from a black spot; compare that part of its surface which was exposed with the part overlapped by other scales; scrape the portion that was exposed; thrust one point of the forceps under the hind edge of a scale, and watch closely this edge, while slowly raising it, to see that a thin skin covers it and passes on to the scale behind. This thin outer skin is chiefly **epidermis.** In this epidermis lie the black **pigment cells** which make the dark spots. A scale with a smooth hinder border is a **cycloid scale**; if the hinder portion is toothed or spiny, the scale is **ctenoid.**

9. A raised line along the side is the **lateral line.** Remove one of the scales on this line, and find what makes the line. Is the line continuous?

10. Make a drawing of the fish as seen from one side, naming all the parts visible. Describe fully all the parts above noted, including the general color and markings.

Use Jordan's *Manual of the Vertebrates* for finding the names of the fishes of your neighborhood.

DISSECTION OF A FISH.

Dissect on a board covered with paper. A few carpet tacks will be needed.

Hold the fish with its back in the palm of the left hand and the tail toward you. Thrust the point of one blade of the scissors obliquely forward through the body wall just in front of the anus, and continue the cut forward half an inch. Now rest the fish on its back and get hold of the edge of the cut with the forceps; as you cut forward in the middle line lift the edge of the body wall to see that no internal organ is injured. When the pelvic fins

are reached, the body wall is stronger and cannot be cut with the tips of the scissors without danger of straining them; lift with the forceps almost enough to raise the fish; insert nearly the whole length of one blade so as to cut near the joint of the scissors between the pelvic fins. Continue the cut to the narrowest part of the isthmus, where it joins the branchiostegal membranes.

1. Observe that most of the internal organs are in one large cavity, called the **body cavity.** Its silvery lining is the **peritoneum.**

2. Near the anterior end of the opening, about opposite the posterior border of the gills, find a transverse partition, the **false diaphragm**; back of this is the main body cavity; in front of the partition is the pericardial cavity, which contains the heart.

3. Keeping the fish still on its back, turn now to the posterior part of the body cavity. While holding the edge of the body wall, use the scalpel handle to push aside the internal organs. Note how yielding is the membrane on which the internal organs rest. Beyond this membrane is the air bladder. Be careful not to cut into it until directed to do so.

4. Turn the abdominal wall outward and note the projections made by the ventral ends of the ribs. Begin again at the point of beginning of the first cut, just in front of the anus, and, with scissors, cut the right side of the body wall along the ends of the ribs as above noted. Continue the cut as far as the bony pectoral arch, just back of the gill opening. Repeat this cut on the left side. Look again at the false diaphragm and its relations to surrounding organs, as it will probably be torn in following subsequent directions. Now turn the two flaps of the body wall well out and forward, and tack them down so as to hold the fish securely resting on its back.

5. In the front part of the body cavity is a dull pink or brownish mass, the **liver,** lying chiefly on the left side of the fish. Raise the hinder edge of the liver, and observe how closely it fits the organs next to it. Press the liver backward, and observe the **hepatic veins** passing forward from the liver through the thin partition, the false diaphragm, in front.

6. Turn the liver to the right, gently tearing away its threadlike attachments. This uncovers a pinkish sac, the **stomach.** Pass a probe back from the mouth and wide gullet into the stomach to determine its shape and extent. Such a stomach as that of the perch, ending blindly at the posterior end, and with the intestine arising from near its anterior end, is said to be **cecal.** Sometimes the posterior end of the stomach of the perch is found turned in, like an inverted glove finger, occasionally to such an extent as to be seen projecting from the gullet into the mouth. Observe a white thread, the **vagus nerve,** distributed over the side of the stomach.

7. Find a large tube, the **intestine,** arising from one side of the stomach. A short distance from its origin, the intestine has several short, blind branches, the **pyloric ceca.** How many are there and how are they arranged? Make a small hole in the end of one cecum; insert the point of a blowpipe and inflate to show the intestine and ceca.

8. Just beyond the ceca, on the posterior surface of the liver, is a thin-walled sac, of a greenish or yellowish color, the **bile sac.** If it contains bile, press on it to show the course of the bile duct to the intestine. When empty, it often has a wormlike appearance. Snip it open with the scissors, or prick it with a dissecting needle to see the bile.

9. Trace the intestine to the anus, observing that it is held in place by a thin, transparent membrane, the **mesentery**; observe the blood tubes in it; tear this away in following the intestine; near the intestine find a small, deep red body, the **spleen.**

10. In the hinder part of the body cavity of the female is the yellow, or pink, **ovary** (varying greatly in size, according to the season). The two white **spermaries** occupy a corresponding position in the male. In some fishes the ovary is single, in others it is double. If double, the two ovaries unite in one tube, which discharges the eggs, the egg tube, or **oviduct.** Trace the oviduct; has it a separate outlet? Sometimes the eggs in the ovary can be discerned.

11. Back of the oviduct or hinder part of the spermaries is a small, pink (sometimes pale green) sac, the urinary bladder. Look for its external opening back of the anus.

12. Gently separate the parts of the digestive tube, and remove any fat that is in the way. Make a diagrammatic sketch of the digestive organs as seen from the ventral aspect, showing and labeling the stomach, intestine, ceca, and the anal opening.

13. Turn now to the pericardial cavity and examine the heart. The red, angular portion of the heart, which in the natural position of the fish lies lowest and hindmost, is the **ventricle**; the darker, more irregular portion lying (in the natural position) above the ventricle, is the **auricle**; the larger blood cavity back of the auricle, and extending across the body cavity, above the false diaphragm, is the **venous sinus**; in front of the ventricle is the light-colored conical **arterial bulb**. This narrows forward into an artery which gives off branches on both sides, one to each gill. Make a drawing of the heart and arterial bulb. After passing through the gills, the blood tubes unite to form the **dorsal aorta**, which passes backward just underneath the spinal column. From above the gills branches also run forward to the head. Cut away and remove the liver, stomach, intestine, and ovary (or spermaries).

14. In the dorsal part of the body cavity is the air bladder. Carefully scrape away some of the thin peritoneal covering and note the thin, transparent wall of the air bladder itself. Scrape away as much as possible of the peritoneum covering the air bladder, in order to see if there are any blood tubes in the walls of the air bladder. Make a puncture in the center of the air bladder. What is the result? Slit the air bladder along most of its length and explore its extent and relations. Except on its ventral surface it is attached to the inside of the walls of the body cavity.

15. Dorsal to the air bladder, extending along the roof of the body cavity, are slender, dark red bodies, the kidneys. With the forceps tear away the false diaphragm and as much as possible of the air bladder. This should disclose the most distinct part of

the kidney, lying anterior to the air bladder and dorsal to the gullet. See if you can trace the kidneys to the urinary bladder.

16. If the mouth and gill covers are not already widely stretched, loosen one or both tacks and set them farther out. Examine the branchiostegal membrane and its supporting rays. Look into the mouth to see the relations between the gills, gill covers, and gullet. Note also the position of the tongue. Cut forward and inward on each side between the gills and the gill covers till the two cuts meet in front of the tongue. Again examine the gills from the front. Pull up the tacks and press the ventral ends of the gills toward the roof of the mouth. Study the action of the joints in the gills. What is the use of the gill rakers?

Observe, where the gills unite above and below, patches of closely set teeth, the **superior** and **inferior pharyngeal teeth.** The bones supporting these teeth, above and below, are the pharyngeal bones. Again depress and raise the lower ends of the gills, observing how the pharyngeal teeth are brought together. What is the probable use of these teeth, and what is the work done by the teeth previously examined?

Remove the gills by cutting the thin membrane back of them, between the isthmus and their ventral ends; above, cut close to the base of the skull.

17. Examine the bones in the posterior border of the gill opening; these are together called the **pectoral arch.** Cut away the flaps of the body wall bearing the fins.

18. Note also the bones supporting the pelvic fins; these are considered as representing the **pelvis.** In the higher fishes the pelvis is fastened to the clavicle; in the lower fishes it is separate from the rest of the skeleton and embedded in the flesh. How is it in the specimen you are studying? Carefully remove the pelvic fins, with the bones which support them; examine and describe them, after scraping away all muscles and other soft tissues.

19. Hold the fish in the left hand, with its back up and its head away from you; insert the point of one blade of the scissors at the base of the caudal fin and cut the skin forward, passing to

the left of the dorsal fin and on to the head. Remove the skin of this side, carefully leaving the white muscles beneath undisturbed; scrape part of the skin clean on the inside; note the arrangement of the scales as seen on each side of the skin; look also for traces of the lateral line on the inside of the skin. Hold the skin up and look through it toward the light, alternately stretching and shortening it, noting especially the lateral line. Roll the skin lengthwise, with the scales outermost, to see how the epidermis passes from one scale to another.

20. Observe the parallel transverse markings on the muscles along the body.

21. Cut and scrape away all the muscle of this side of the body down to the bones, and make out the central backbone, with its bony projections above and below. Bend the dorsal and anal fins from side to side, to show the bones which support these fins and the relation of these fin supporters to the projections of the backbone.

22. Break across the backbone under the center of the second dorsal fin, and remove one piece, or **vertebra**, of the backbone; clear away all muscle and other tissue, and make out the following parts:—

a. The central body, or **centrum**, shaped like an hourglass and hollowed at each end.

b. Two projections extending upward, soon uniting to form one spine, the **neural spine**.

c. The archway formed above the body of the vertebra is the **neural arch**.

d. A similar arrangement below, forming the **hemal arch** and **hemal spine**.

Make a drawing of this vertebra as seen from the side; another as seen from the front.

23. In like manner remove and study a vertebra from a point opposite the center of the first dorsal fin, with the ribs attached to it. What are the differences between these two vertebræ?

24. Thoroughly clean the last vertebra, and study carefully its relations to the caudal fin.

25. Observe the white **spinal cord** in the tube formed by the neural arches above the bodies of the vertebræ. This is the nerve tube, or **neural tube**; note also the blood tubes in the corresponding **hemal tube,** below.

THE BRAIN OF THE FISH.

Cut off the head; clear away the muscles at the back of the head; carefully slice off the top of the skull with a strong, sharp knife; with extreme care cut away the roof of the brain cavity; a mass of loose, gray tissue covers the brain, which is of a white or pinkish color; cautiously pick away this loose tissue, using a small syringe, or medicine dropper, to wash away the loosened matter. Make out the following parts of the brain, beginning at the posterior end: —

1. The cut-off end of the spinal cord.

2. The widened part of the spinal cord, where it passes under the hinder part of the brain, is the **spinal bulb.**

3. The hinder, undivided part of the brain is the **cerebellum.**

4. In front of the cerebellum are the two large, rounded **optic lobes,** forming the widest part of the brain.

5. In front of the optic lobes are two oval masses which meet in the middle line; these are the **cerebral hemispheres,** and together they constitute the **cerebrum.**

6. Observe the **olfactory lobes** tapering forward in front of the cerebral hemispheres; from these trace the **olfactory nerves** to the nasal cavities.

Make a drawing of the brain as seen from above, naming all these parts. Cut open one of the optic lobes and note that it is hollow; push the eyes outward and find a white cord extending inward and backward from each. These are the **optic nerves.**

THE MUSCLES OF THE EYE.

1. Cut away the upper part of the eye sockets and find in each a muscle extending outward and backward from the anterior part of the socket to the top of the eyeball. This is the **superior oblique muscle.**

2. Another muscle coming from the posterior part of the socket will be seen passing forward to be attached under the oblique muscle. This is the **superior rectus.** Make a drawing showing these muscles. The other eye muscles may be more easily examined from beneath.

If the under surface of the skull of the specimen previously studied be not injured, it may be used; otherwise, cut off the head of another fish, and cut away completely the lower jaw and the floor of the mouth. Move the gill covers in and out to show more clearly the thin plates of cartilage between the eyes and the roof of the mouth; with scissors slit in the middle line the tough membrane lining the roof of the mouth, and strip it out to the sides. Observe a muscle running outward from each side of the base of the skull to the corresponding gill cover. Cut these at their inner ends and turn them outward. With scissors cut away the cartilages covering the under surfaces of the eyes.

3. Observe a muscle passing outward from the front part of the socket to the eyeball, the **inferior oblique muscle.**

4. The muscle running forward close to the partition between the eyes is the **internal rectus.**

5. On the under surface of the eye is the **inferior rectus.**

6. Attached to the hinder border of the eye is the larger **external rectus.** Note carefully the origin of each of these, their place of insertion on the eyeball, and their change of shape in their course; consider the effect of each on the eye.

Observe the thin-walled swellings at the sides of the base of the hinder part of the skull; cut into these **ear capsules** and find in each a membranous sac, the **vestibule** of the ear. In this sac lies the "ear bone" or **otolith.** Find the white optic nerve arising from the inner surface of the eyeball; with a sharp knife cautiously cut away the base of the skull and trace the optic nerves to the brain; demonstrate that they cross each other, the optic nerve from the right eye entering the left half of the brain, and *vice versa.*

Make a drawing showing this view of the brain and eyes; open one of the eyes and remove the spherical crystalline lens.

Topics for Reports. — The Sources, Methods of Capture, and the Commercial Importance of Food Fishes, — such as Codfish, Mackerel, Flounder, Halibut, Herring, Shad, Sardines, Whitefish, Lake Trout, Catfish, Carp, Buffalo, etc. Fish Hatcheries. The Salmon Industry. Life History of a Salmon. United States Fish Commission. Caviar. Isinglass. Cod-liver Oil. Fish Oil.

Read *American Natural History*, Hornaday.

CHAPTER IX.

AMPHIBIA.

FIELD STUDY OF FROGS.

CLAD in rubber boots, the student can visit the frogs at their home. Walk along the bank of a creek, or wade through a marsh. Try to "see the frogs before they see you." But if they see you first and jump or swim away, try to follow them up and see where they go. Do they soon reappear? How does their color suit their surroundings? Would you suggest a more suitable color? What seems to be the main idea in the colors they show? What reason for the difference of color of the dorsal and ventral surfaces? What enemies has the frog that would discover it from above? How does its dorsal color serve it? Compare its color with that of its surroundings. Why should a frog be white beneath? What enemies has a frog that would see it from beneath? What effect would the white color have? Suppose the frog were dark below; would it make any difference in the ease with which it could be seen from below? Suppose it were spotted over the ventral surface as it is over the dorsal surface? When a frog is floating, how much is out of water? What parts of it are out of water? In the spring watch the frogs that congregate in ponds. Do they all croak? If not all, which ones do the croaking? Watch to see how the eggs are laid. What are the eggs like? How are they placed? In still water or in a current? In deep water or shallow? Do any animals eat the eggs? How long does it take for the eggs to hatch? Take the temperature of the water and see if this makes any difference. Do the eggs all hatch nearly at the same time, or is there considerable difference? Do many of the eggs fail to hatch?

Again in the fall study the frogs when they gather once more along the banks. See if you can find any of them in the act of diving into the mud. Mark carefully some of these places, and watch to see if the frogs come out again. Some very slight covering of leaves or sediment may serve to show whether or not the frog has come out. How deep do they go? Do they change their depth or position during the winter? What is the temperature of the mud at this time? How cold does the mud at the bottom of creeks and rivers become during the coldest part of winter? Does it vary much during the winter?

LABORATORY STUDY OF THE LIVE FROG.

1. Put a live frog into a tub of water and study carefully its mode of swimming and floating.

2. Notice how the frog sits when at rest. Make drawings of the live frog in the sitting posture.

3. What has the frog in common with other animals that jump well?

4. Watch closely the frog's breathing, paying especial attention to the throat, nostrils, and sides.

5. Touch the eyeball with a pencil, and note what follows. Note the motions of the eyelids. Note the color of the frog's eyes. What is the shape of the pupil?

6. Test the frog's sense of hearing.

7. What does the frog eat, and how does it take its food?

8. Look for slight pulsations near the end of the backbone on each side, near the anus. These are the beatings of the **lymph-hearts.**

9. Keep one frog in the light and another in the dark and compare their colors after an hour. Vary the color surroundings to see whether they affect the color of a frog.

EXTERNAL FEATURES OF THE FROG.

Kill a frog by wrapping it in a towel or piece of cloth of any kind, and moistening the latter with chloroform; or put a tea-

spoonful of ether in a fruit jar nearly full of water, immerse the frog in it, and cap the jar.

1. Has the frog a neck? Find the division between the head and the body by bending the parts and feeling for the joint.

2. Back of and below each eye is an oval area, the membrane of the eardrum, or **tympanum.**

3. The fore limb consists of the **arm, forearm,** and **hand.**

4. The hind limb consists of the **thigh, leg,** and **foot.**

5. Count the fingers and toes.

6. What differences are there between the fore and hind limbs?

7. Open the mouth, seize the tongue with the forceps and draw it forward; observe that it is attached in front, but free behind. How is such a tongue used?

8. Look closely for teeth. Where are they?

9. Pass a bristle tipped with sealing wax into one of the nostrils. Where does it enter the mouth?

10. Make a small opening in one of the tympanic membranes, pass a bristle through this opening, and look for its appearance in the mouth. The opening through which it appears is the **Eustachian tube.**

11. The mouth narrows back into the gullet.

12. In the back part of the floor of the mouth is a small slit, the **glottis**, leading to the lungs.

13. Compare the colors and markings of the upper and lower surfaces of the frog; draw dorsal and ventral views of the dead specimen, naming all visible parts.

Use Jordan's *Manual of the Vertebrates* for finding the names of any amphibians.

DISSECTION OF A FROG

1. Lay the frog on its back in a dissecting pan. Stretch out the fore limbs close to one end of the board and tack to the board through the hands; then stretch the hind limbs well back and out and tack the feet so the body will be firmly held. Common carpet tacks can be set firmly enough by pressing with the thumb, and will not need hammering. With forceps pinch up a fold of skin

near the pelvis. With scissors snip through the skin in the middle line. Holding the edge of the skin with the forceps, slit the skin from the pelvis to the chin. Loosen the skin wherever it adheres to the underlying tissues, and turn it back. Cut outward in the middle of each flap of skin, and pin out if necessary to keep it out of the way. Now cut through the muscular wall of the abdomen in the same way, but be careful to keep to one side of the middle line, and thus avoid cutting the central blood tube. Be also especially careful to lift the edge of the cut with the forceps, and watch closely the lower point of the scissors to see that none of the abdominal organs are injured. When the breastbone is reached, raise it to see the heart. Now cut through the breastbone a little to one side. Loosen the tacks in the hands and set them farther out to expose the organs; tack out the flaps of the abdominal wall. Keep the specimen covered with water; renew the water if it becomes turbid.

2. Covering most of the internal organs is the dark **liver**, consisting of several lobes; note how many lobes there are and how they are arranged. Slip the handle of the scalpel under the posterior border of the liver and tip it forward. Observe the **bile sac**, a dark, usually bluish, spherical sac, connected with the liver.

3. Between the lobes of the liver at its anterior edge is the reddish **heart**. It is inclosed in a very thin sac called the **pericardium**. Pinch this up with the forceps, cut through it, then remove most of it. The heart consists of two auricles at the base, and the single ventricle at the apex, or posterior end. In a freshly killed frog the heart often may be seen beating. Time its pulsations. Running forward from the ventricle is the main artery. This divides into two branches, right and left, each of which has three subdivisions: —

a. To the head, the **carotid artery**.

b. To the body generally, the **aorta**. The two aortæ unite in the posterior dorsal part of the body cavity.

c. To the lungs and skin, the **pulmo-cutaneous**.

What is the effect of applying gentle heat to the heart, as by

breathing on it? Touch it with the point of the forceps. **Does** this affect it?

4. Push the liver to the right and expose the pale **stomach.** Use the blowpipe as a probe and push it back through the mouth into the stomach. For this it may be necessary to lift the anterior end of the board. Looking back into the mouth, the puckering of the gullet may be seen. Are the mouthfuls that the frog swallows small or large, relatively? What is the real width of the gullet?

5. At the posterior end of the stomach begins the **intestine**; carefully trace it throughout its course.

6. The widened portion of the intestine near its end is the **cloaca.** The external opening is the **anus.**

7. The thin membrane that holds the intestine in place is the **mesentery.** To what is it attached dorsally? In a freshly killed specimen blood tubes may be seen in the mesentery. The mesentery is a double membrane and the blood tubes and pancreas lie between the two folds.

8. Turn the stomach and intestine forward; the **pancreas** should be seen in the loop formed by the intestine and stomach. It has the appearance of a yellow cord, and is often hard to distinguish.

9. At each side of the body cavity, usually concealed by the lobes of the liver, are the two lungs. In frogs killed by chloroform the lungs are usually collapsed, that is, emptied of air; hence they are small and dark-colored. If they contain air, they may be very conspicuous and bright-colored. Find again the glottis, or entrance of air from the floor of the mouth; insert the tip of the blowpipe and inflate the lungs. They are nearly plain, hollow sacs, and not spongy all the way through like the lungs of the mammals. Tie a thread tightly around the base of each lung while it is inflated; cut the lungs out and hang them up till they are dry. Then cut one of them open and compare it with the lung of a turtle similarly prepared.

10. Insert the scalpel handle under the posterior end of the stomach, and tip it forward with the intestine and the liver. On

each side of the cloaca is a flattened reddish body, the **kidney**. The ventral face of each usually shows a yellowish streak.

11. Near the ventral surface of each kidney, in the male frog, is the white, oblong **spermary**.

12. In the female, the **ovary** occupies a corresponding position; but often the ovaries are found greatly distended by eggs, so much so that they occupy the larger part of the body cavity. The eggs are black and white. The ovaries are held within the two folds of the mesentery, hence, when distended with eggs, they present a much folded and plaited appearance. The **oviducts** are long, convoluted, whitish tubes, occupying considerable space in the dorsal part of the body cavity on each side. With fine scissors make a small slit in one of the oviducts near the posterior end, and insert a dark bristle to find the opening into the cloaca. Make a similar opening near the anterior end of the oviduct and probe to find the opening by which the eggs enter the duct at its free end in the body cavity near the base of the lung.

13. Connected with the ovaries and spermaries are usually several fingerlike masses of yellow fat.

14. Close to the anterior end of the cloaca is the small, red, spherical **spleen**.

15. In the extreme posterior end of the body cavity is the **urinary bladder**. It is a thin, delicate sac, which is usually found empty, and floats upward in the water like a mere fold of nearly transparent membrane. Insert the blowpipe through the anus and inflate. This should reveal its shape and size, if it has not been perforated.

The Circulation of Blood in the Web of a Frog's Foot. — For this get a frog with a pale web. Take a piece of shingle six inches long and three inches wide. Cut a round hole, half an inch in diameter, near one end of it. Wrap the frog in a wet cloth, with one leg projecting, and tie it, thus wrapped, to the shingle. Tie threads around two of the toes, and stretch the web, but not too tightly, over the hole. Place the shingle firmly on the stage of a microscope. Examine first with a low power. The large tubes

which grow smaller by subdivision are **arteries.** The large tubes which are formed by the union of smaller ones are the **veins.** The finer tubes, forming a network in every direction, are the **capillaries.** They receive the blood from the arteries and pass it on to the veins.

Put on a higher power, a one-fifth or one-sixth objective. Study the little bodies floating in the blood. These are the **corpuscles.**

1. The colored corpuscles. The faintly colored elliptical corpuscles; do they change their shape when pressed, as in turning a corner? What is the color of these corpuscles? Mold a bit of clay into the shape of one of these bodies.

2. The colorless corpuscles. The smaller, rounder, paler corpuscles, fewer in number and moving with a slower and more unsteady motion along the sides of the channel, — what must be the shape of these? Place a drop of frog's blood on a slide, cover with a cover slip, and examine with a high power. Make careful drawings of the two kinds of corpuscles.

THE NERVOUS SYSTEM OF THE FROG.

The nervous system is better seen in alcoholic specimens. Slit the skin along the back from the snout to the anus; with a sharp knife cautiously cut away the top of the skull, and find: —

1. Between the eyes, side by side, two elongated white bodies, the two halves, or **hemispheres**, of the **cerebrum.** Observe two small, pear-shaped bodies, the **olfactory lobes,** in front of the cerebral hemispheres. These taper forward into nerves running to the nasal region; these are the nerves of smell, or **olfactory nerves.**

2. Back of the cerebral hemispheres are the **optic lobes,** forming the widest part of the brain. Prove that a white cord, the **optic nerve,** connects each of these lobes with one of the eyes; does the optic nerve extend directly from each eye to the corresponding optic lobe? Loosen and raise the brain from the front to prove these points.

3. Extending backward from the under side of the optic lobes is the **spinal bulb.**

4. The spinal bulb narrows and becomes the **spinal cord.** Trace the spinal cord back into the spinal column, cutting away the part of the backbone that covers it.

5. In the body cavity find nerves emerging from the sides of the spinal column, hence called the **spinal nerves.** Find that several of these, after running backward, unite to form one large nerve. Trace the nerve down between the muscles of the thigh; this is the **sciatic nerve.**

REFLEX ACTION OF THE FROG'S SPINAL CORD.

Chloroform a frog as directed on page 83. As soon as it becomes insensible find, by bending the head, the joint between the head and the backbone; lay the frog on a board, and quickly thrust the blade of a knife through the body at this joint, and completely sever the spinal column and spinal cord. This is essentially the same as cutting off the head. Run a wire into the brain cavity and stir it about in order to destroy the brain. In a few minutes hang the frog by a hook through the jaw.

1. Pinch the toes; what follows? Repeat the experiment several times. Pinch the skin near the anus.

2. Slit the skin along the back side of the thigh; tear apart the muscles, and find the sciatic nerve; with a sharp pair of scissors (while watching closely the foot) sever this nerve; what takes place?

3. Hang up as before, and pinch the toes of each foot; what difference is now observed?

4. With the forceps alternately pinch the two ends of the severed sciatic nerve; what takes place as these two ends are pinched?

5. Run a wire down the spinal column, twisting it about to destroy the spinal cord; what occurs while this is doing?

6. Pinch the toes as before; what results?

7. Again pinch the end of the sciatic nerve, still connected with the parts below, being careful to pinch a little lower than before.

The Action of a Frog's Muscle. — Kill a frog thus: Into a fruit jar of water put a teaspoonful of ether; immerse the frog in it and cap the jar. As soon as the frog is motionless cut off its head and run a wire down the cavity of the spinal column, to destroy the spinal cord. Cut through the skin around the base of one of the thighs, and strip off the skin from the whole of the limb. Note that the muscles are of a pale color. The muscles of a frog's thigh are nearly the same in number and arrangement as in man. Examine more thoroughly the calf muscle; the end by which it is attached below is its **insertion**, and the upper attachment is its **origin.** The white cord in which it ends is its **tendon.** This tendon is often called the "heel cord," or Achilles' tendon.

Sever the limb from the body at the hip joint. Separate the muscles along the outer back part of the thigh, and find the white, threadlike **sciatic nerve**. The nerve must be handled with great care; it must not be pinched or dragged. Carefully separate it from the surrounding muscles, and turn it down upon the calf muscle. Cut away all the muscles of the thigh, being careful not to touch the nerve where it runs down by the knee. Sever the heel cord below the heel, and separate the calf muscle from the rest of the leg, leaving undisturbed its attachment above; just below the knee cut away the shin bone, with all the muscles of the leg except the calf muscle.

There should now remain the **thigh bone,** with the **sciatic nerve** running to the **calf muscle** suspended below. Fasten the thigh bone to some support, such as a clamp on a retort stand. Attach a small hook to the tendon, and suspend from it a slight weight, such as a small key.

Such a preparation is called a **nerve-muscle preparation.** It should frequently be moistened with a .7 per cent solution of common salt in water, called **normal saline solution.**

Now take a sharp pair of scissors, and snip off the shortest possible portion of the upper end of the sciatic nerve. If the muscle is closely watched at the time when the nerve is cut, it will be seen to thicken and shorten, and to lift the weight. If the muscle

be held between the thumb and finger while the nerve is pinched (and the scissors are the surest pinchers), it will be felt to harden.

This experiment should be repeated, varying the weight, until it is made very clear that when the nerve is stimulated the **muscle shortens** (which is the most important fact about the action), thickens, and grows harder.

Observe the thin, transparent membrane covering the muscle, the **muscle sheath.** Tear the muscle to pieces, and note its fibrous structure. Put a bit of the muscle in a drop of water on a slide, and cover with a cover slip ; examine first with a low, and then with a high, power, to see the cross markings of its finest fibers. This kind of muscle is called **striped** or **striated.**

PREPARATION OF A FROG'S SKELETON.

Remove the skin and all the soft tissues. If you have a specimen that has been used for dissection, of course the anterior limbs will come apart where the breastbone was severed. Remove the soft tissues mainly by means of the scissors, being careful not to cut too close to the joints. If the work is not completed at once, return the specimen to the water. Renew the water frequently and do not allow it to "get bad." If the ligaments decay, the bones will fall asunder and make great difficulty on account of their number and smallness. Do not boil the skeleton, or put it into alkali. These processes may be useful for larger skeletons, but are not good for such small ones as that of the frog.

MOUNTING A FROG'S SKELETON.

Get a piece of stiff, dark cardboard about six by eight inches. Before mounting the skeleton on the card, get it nearly dry by placing it on blotting paper or on cloth. If it is too dry, it will be brittle ; if too wet, it will stain the card. Draw a fine pencil line along the middle of the card. Place the skeleton along this line and double up the limbs as if the frog were in the resting position. A block of cork must be placed under the anterior end of the spinal column to hold it up to the level of the skull. A small

cork wedge should be placed between the jaws. The skeleton is to be sewed to the card with a single thread of the color of the bones. The bones are to be held by loops that pass up from the under side of the card, around the bone, and back through the same hole. *All holes are to be punctured from the upper surface of the card*, and are better made with a pin slightly larger than the needle used in sewing. It is important to determine exactly where each bone is to lie, so that the hole may be made exactly under the middle of the bone. Now puncture holes as directed under the front and hind angles of the jaws, and under the pelvis beneath the hip joints. After securing the head and pelvis, determine carefully where the bones of the limbs are to rest. Pass loops around near each end of the longer bones, but a single loop in the middle will serve for the short bones of the fingers and toes. If the skeleton is from a specimen used for dissection, the breastbone will have been severed. Bring the cut ends together and sew firmly in place. The shoulder blades should meet in the middle line a short distance back of the skull. Print the label "Skeleton of a Frog" at the foot of the card and write your name on the back of the card.

To preserve the skeleton get a shallow box, such as a shallow cigar box. Fit the card to the box and tack it to the bottom. A good plan is to remove the wooden cover and replace it with a glass lid. Paste strips of paper or suitable cloth along the edges, and the case will exclude dust.

THE FROG'S SKELETON.

1. Note how open and light the skull is, and how easily the bones are cut.

2. Count the parts of the spinal column; these are the **vertebræ**. The long bone terminating the spinal column is the **urostyle.**

3. Observe the long bones of the **pelvis**, parallel with the urostyle. What makes the frog humpbacked?

4. The fore limb has, in the upper arm, the **humerus**; in the forearm, the **radius** (same side as the thumb) and the **ulna**; in the

wrist are several small bones, the whole collectively called the **carpus**; in the hand are the **digits.**

5. The hind limb has, in the thigh, the **femur**; in the leg, a bone which shows, by grooves near its ends, that it is formed by the union of the two bones corresponding to the **tibia** and **fibula** of man; the several small bones of the ankle are together called the **tarsus**; the bones of the toes are the **digits.**

6. Are there any ribs?

STUDY OF A TADPOLE.

Get a number of frog's eggs and place them in a jar of water. If many eggs are placed in a small amount of water, the eggs are not likely to develop well. Set different jars in different places with regard to light and heat, and note any differences in results. It is best to have some aquatic plants in the jar, especially after the young have hatched out. How long before the tadpole within the egg begins to move? How long till it breaks away from the egg mass? How early do the gills show themselves? What are the parts of the tadpole? What is the shape of the tail? What is its use? How is it used? How early do legs appear? Which legs develop first? Is there any reason for this? Are tadpoles relatively active or inactive? Do they move much "of their own accord"? Or chiefly when they are disturbed? Does the tail fin have supporting rays like the fin of a fish? What do tadpoles eat? How do they eat? Have they teeth? Is the growth slow or rapid?

Put a tadpole in a watch glass of water under the microscope, with a half-inch or two-thirds-inch objective, and watch the circulation of blood in the gills. What becomes of the gills? Watch the sides of the body for a hole where water escapes. Where is it? Why is the tadpole not symmetrical in this respect? What becomes of the tail as the tadpole becomes a frog?

Examine a dead tadpole to see if there are teeth. What is the size of the mouth in proportion to that of the adult? Look again for the hole on one side of the body. Are there ever limbs con-

cealed? Open the body cavity. Is the digestive tube long or short as compared with that of the frog? What reason for this? Can you find any traces of gills? Of lungs? Is there a backbone? Do you find a brain and spinal cord?

Make a series of drawings showing the different stages of development.

Topics for Reports. — Frogs as Food. The Axolotl. Value of Toads. The Tree Toad.

Read *American Natural History*, Hornaday.

CHAPTER X.

REPTILIA.

FIELD STUDY OF SNAKES.

First try to rid yourself of prejudice against snakes. It is not necessary to handle them, and poisonous snakes are now rare in most places. If the snake has been frightened by you, try to learn how he became aware of your presence. Was it through sight, hearing, or some other sense? Is there any plan in his escape? Does he seek shelter, or simply move away from you? Are his colors such as to aid him in escaping enemies? Why are we usually surprised when we happen upon a snake? Is the snake also surprised?

Study the snake's mode of locomotion. Have you ever seen the trail made by a snake, as in a dusty road? Does the nature of the surface make any difference in the ease with which it travels? Does a snake ever crawl otherwise than in a wavy line?

If you happen upon a snake that has not already discovered you, watch it. Try to find out what it is doing. Especially if you find a snake eating, take time to learn how it eats. Does it kill the prey before swallowing it? Does it chew its food? If you kill a snake, or see one killed, where you cannot take it home, find out, if possible, what it has been eating. If the snake is much bulged out at, or in front of, the middle, you may suspect that it has just swallowed a meal. Do snakes "charm" birds?

Have you ever found a shed skin of a snake? If you find one, bring it to the class. How much of the external markings is shown on the shed skin? Can all snakes swim? If you get a garter, or other snake, not a water snake, and do not wish to keep it, throw it into water to see if it can swim. Will the body of a

freshly killed snake sink or float? Do snakes dive? How do snakes strike, when capturing prey or in self-defense? How far can a snake strike? Let it strike some object, for example a stretched paper, to show with what force it strikes. Do you *know* of any case where a snake, unmolested, pursued a human being?

LABORATORY STUDY OF A LIVE SNAKE.

A snake may be kept in a large glass jar, but it is better to have a shallow box, with glass lid. Test the snake's vision. Does it see well? Does it see small objects as readily as large ones? Does it notice slow motions as well as quick ones? Test its sense of hearing. Try music. Does the snake protrude the tongue? If so, for what purpose?

Induce the snake to strike; study the position and mode of striking. Study the process of respiration in the snake. Is there a pause? What movement is first after the pause? Compare the snake's respiration with your own. Does a snake need much or little oxygen as compared with man?

How soon does a snake become hungry after a meal? Offer various articles of food. Does a snake drink? Offer it water in a shallow dish from time to time. Will a snake eat a dead animal? Do snakes of different kinds in the same box offer to molest each other? Do snakes ever eat snakes of any kind? Do snakes sleep? At what times are they most active? When least so? Watch a snake to see the shedding of the skin. At what point does the skin begin to loosen? How is the skin peeled off? What is the condition of the snake before shedding? What is the appearance and condition after shedding? How often does a snake shed its skin?

EXTERNAL FEATURES OF A SNAKE.

Examine the scales; observe their relation to each other and to the skin. A scale having a ridge running lengthwise in the middle line is **carinated**; if there be no such ridge, the scale is called **smooth**. How many rows of scales are there, not counting the

wide **ventral plates** below? It is usually easier to keep the count by following the row of scales **obliquely** across the body.

Use Jordan's *Manual of the Vertebrates* for finding the names of any reptiles found in your vicinity.

DISSECTION OF A SNAKE.

Get a large snake, a paper of tacks, and a board as long as the snake. The board should be of dressed soft pine so that the tacks may be inserted by the thumbs; a hammer should be unnecessary, tho if the spinal cord is not destroyed, the body may pull with considerable force, and it may be desirable to drive a six-penny nail firmly through the tail just back of the anus. Lay the snake on its back, with the head at one end of the board. Push the point of a tack into the mouth at one side, and drive it through the upper jaw, leaving the lower jaw free. Repeat with the other side. Stretch the snake out straight, and tack through the tail, just back of the vent. With the forceps pinch up a fold of the skin of the throat, and cut through it with the scissors. The greatest danger is that of cutting into the air sac, which, when distended, fills most of the space of the body cavity. To guard against cutting into it push the handle of a small spoon, or the bowl of an "after-dinner coffee spoon," along under the skin ahead of the scissors so the lower point of the scissors shall be constantly guarded. Continue the cut back along the middle line of the ventral wall, being very careful not to cut anything within. As the cut proceeds, stretch the skin out at the sides, and tack it down every two or three inches. Cut away the thin membrane which extends across from the ribs on each side, avoiding blood tubes.

1. With forceps seize the lower jaw and pull the mouth open. Note how dilatable the mouth is, and how loosely the lower jaw is hinged to the upper; note, also, that the right and left halves of the jaws do not unite in front. Examine closely the **teeth,** their shape and arrangement. In what direction do they point?

2. Seize the **tongue,** and draw it forward from its sheath in the floor of the mouth. Observe its black, forked tip.

3. Above the tongue find a small opening, the **entrance to the** windpipe. It is called the **glottis.**

4. Take six inches of glass tubing half an inch in diameter; slip over the end of this a piece of rubber tubing a foot long; this will enable you to see the effect while you are inflating. Insert the glass tube into the throat through the mouth; pinch the walls of the gullet closely around the blowpipe, and inflate the wide **gullet** and **stomach.**

5. For inflating the lung, a tube with a small point is better; draw out a small glass tube, and connect with a rubber tube; insert the point in the glottis, and inflate. This locates the pink **lung,** with its posterior, thin-walled extension, or air sac. How far back does the air sac extend?

6. Trace from the glottis to the lungs the ringed windpipe, or **trachea.** Only one lung is developed; look for the rudiment of the other.

7. In a freshly killed snake the heart will be noticed on account of its beating; the part of it farthest from the head is the **ventricle**; nearer the head find two parts, the right and left **auricles.** These two contract at the same time, just before the contraction of the ventricle. The heart is in a thin sac, the **pericardium**; pinch up a fold of this with the forceps, and cut into it, and remove that part of it covering the heart, very carefully avoiding blood tubes.

8. Find a blood tube arising from the ventricle just between the auricles, and passing forward between them, curving around over the gullet to the posterior part of the body. This is the main artery, or **aorta**; look for its branches running to the head.

9. Look also for an artery running to the lung, the **pulmonary** artery.

10. Find several **veins,** of a darker color than the arteries, leading to the heart.

11. Alongside the stomach is a dark red body, the **liver**; a large vein runs along its surface.

12. Back of the liver is the dark **bile sac**; the ducts from the liver to the bile sac, and from the bile sac to the intestine, are not easily seen.

13. Just posterior to the bile sac is the spherical, reddish **spleen.**

14. Closely following the spleen is the pale, roundish **pancreas**; the duct by which its secretion is conveyed to the intestine is hard to find.

15. Clear away any masses of fat that may hide organs in the posterior part of the body, and expose the **intestine** from the stomach to the anal opening.

16. The enlargement of the intestine near its termination is the **cloaca.** Again inflate the stomach; does this also inflate the intestine?

17. If the specimen is a female, there may be found, in the posterior part of the body, the whitish **ovaries,** with a row of white eggs; from the ovary, the **oviduct,** a slender pinkish tube, extends back to enter the cloaca. Are the ovaries of the two sides opposite each other? Slit into one of the oviducts near the cloaca; insert a bristle and find where it enters the cloaca.

18. In the male the white **spermaries** have similar positions. Their ducts are called **sperm ducts.**

19. Farther back than the ovaries are the dark red, elongated **kidneys.** Describe them. Trace their ducts, the **ureters,** to the cloaca.

20. Count the ribs of one side.

21. Draw the points of the forceps quickly along the muscles over the ribs; note the shortening of the muscles that follow; such action of the muscles is wholly involuntary (as the brain now has no connection with the body), and is called **reflex action of the spinal cord.** It is the same kind of action as that seen in the case of a chicken with its head cut off.

PREPARATION OF A SNAKE SKIN.

After finishing the dissection according to the above directions, completely remove the skin, retaining only the skull. Thoroughly rub the inside with arsenic. Make a wooden body, around which wrap a little cotton, and sew up as neatly as possible. Try

to preserve the original size of the snake. Lay the prepared skin on a shelf till it is dry. Keep it in a dust-proof case.

Topics for Reports.—The Cobra. Other Venomous Snakes. Do Snakes swallow their Young? The Python. The Boa Constrictor.

FIELD STUDY OF TURTLES.

The student soon learns that the common pond and mud turtles are shy creatures. Along ponds and streams one may see them on logs and stumps. But one must go quietly and cautiously, or he will scare them all into the water. On which sense do they rely, sight or hearing, to discover enemies? Watch their method of getting into the water. Do they soon return, if the observer is quiet? What seems to be their object in thus perching on logs? Find out, if you can, what they eat, and whether they eat on land or in water. Do they require much or little food?

Can you find where and how they lay their eggs? Do they care for the eggs? How long does it take the eggs to hatch? Do the parents care for the young? What are the prevailing colors of turtles? How do these colors compare with their surroundings?

STUDY OF A LIVE TURTLE.

Watch a turtle walk on a floor. Does it walk or crawl? Is the body lifted above the surface or does it drag? How are the limbs used? Put the turtle in water and find out how it swims. Does it use the front feet alternately or at the same time? Are the feet webbed? Does it swim rapidly or slowly? Does the turtle dive? If there is mud at the bottom, does it attempt to burrow into or bury itself in it?

Feed the turtle and find what it likes best. Does it eat little or much? Do turtles become tame in captivity? Do they recognize those who care for them, and distinguish them from strangers?

Can you see how the turtle breathes? Can it stay under water long?

What parts of the turtle can be protruded beyond the margin

of the shell? How does it protect these parts? Can any part of the shell be moved, or is it wholly rigid?

EXTERNAL FEATURES OF A TURTLE.

1. The upper part of the shell is the **carapace.**

2. The under part is the **plastron.**

3. Observe the large sections, or **plates**, marking the shell. How many of these plates are there on the carapace? How many on the plastron? How are they arranged?

4. Study the motions of the head, legs, and tail; observe the **scales** on these parts.

5. Note the shape of the feet; for how many purposes does the turtle use its feet? Are the feet of all turtles alike? Count the claws; compare the front and hind feet.

6. With a strong pair of pinchers seize the head, pull it well out, and chop it off; examine the mouth; are teeth present? Is there a tongue? Look for a third eyelid. Compare with the pigeon in this point of structure.

DISSECTION OF THE TURTLE.

Saw through the bridge which connects the carapace and plastron on each side. Carefully raise the plastron, and, keeping the blade of the knife or scalpel close to its inner surface, cut away all its attachments to the organs within, and remove it entirely.

1. In front are the bones supporting the fore limbs.

2. Behind are the bones of the **pelvis**, supporting the hind limbs. Were these two sets of bones attached to the plastron?

3. A thin membrane covers the internal organs; through it the **heart** may be seen beating. Cautiously avoiding blood tubes, cut away this thin covering, and distinguish the following parts of the heart: —

a. The large, hinder part, the **ventricle.**

b. In front, on each side, the two **auricles.**

c. Between the auricles are blood tubes, branching toward the

head. As in the frog, there are two aortæ, the right and left, which unite posteriorly.

4. Make out the following order of the heart's beat: —

a. The contraction of the blood tubes leading to the auricles.

b. The contraction of the auricles.

c. The contraction of the ventricle.

5. On each side of the heart appears the dark **liver**, consisting of two main lobes, connected by a cross-band. Search the liver to find the **bile sac.**

6. Under the left lobe of the liver is the **stomach.**

7. From the stomach trace the intestine to the transverse vent under the tail.

8. Masses of eggs may be found in the **ovary** (if a female).

9. Find a large bladder near the pelvis.

10. Raise the liver to find the **lungs**; pull forward the neck, find the windpipe, and insert a blowpipe. By inflating, the lungs may be better seen. When the lungs are fully inflated, tie a string tightly around the windpipe; carefully remove the lungs, and hang them up to dry. When they are thoroughly dry and firm, cut them across, and compare with the lungs of the frog and rabbit.

11. How does the turtle draw in its head?

12. How long does the heart beat after the head is cut off?

THE SKELETON OF THE TURTLE.

1. Clean away the muscles and all soft parts. Boiling loosens the outer plates; these are parts of the skin, and not of the skeleton proper; they are called the **epidermal plates.**

2. When these plates are removed from the carapace, there appears a series of bones extending outward on each side; these are the ribs, very wide, and united by their edges. How many of these flattened ribs are there?

3. On looking at the inner surface of the carapace, the series of **vertebræ** will be found; and attached to the sides of the bodies of these vertebræ are the heads of the ribs.

4. Along the middle line of the outside of the carapace, between

the ribs of the two sides, is found a series of bony plates; these are the enlarged and flattened projections of the vertebræ; they correspond to the spines which make the sharp ridge along the backs of most vertebrates.

5. Compare the bones of the pelvis and of the limbs with those of the rabbit.

Topics for Report. — The Terrapin. The Hawkbill Turtle. Tortoise-shell. The Loggerhead Turtle. The Green Turtle. The Snapping Turtle. The Soft-shell Turtle. The Gopher.

Read *American Natural History*, Hornaday.

CHAPTER XI.

AVES.

OUTDOOR STUDY OF BIRDS.

THE following set of questions is general and may be applied to any bird that comes within our range of observation. The English sparrow serves well for study, since — like the poor — it is always with us. These studies should include a careful study of the domesticated birds.

Place of Living. — Does the bird stay most of the time on the ground or in the trees? In open fields or in thickets? In open woods, or dense forest? On dry soil, or along the water? Is it fitted for perching, running, swimming, wading, climbing, or for what general kind of life?

Flying. — Does it fly swiftly or slowly? Do the wings vibrate rapidly as in the quail, or slowly as in a hawk? Is the vibration uniform, or do the wings make a series of rapid motions, followed by a rest during which time the bird sails, as with the quail? Is the flight quiet as in owls, or accompanied by a whirring sound as with a quail? Is the flight in comparatively straight lines, or in loops or festoons, as with woodpeckers? Does the bird ever "soar," or "hover"? What is the use of the tail in flying? How are the legs and feet held during flight? Why do some birds fly most of the time while others fly little? What characteristics have the birds that spend much of the time flying? Name some of the best flyers you know. Name some of the poorest flyers that live near you.

Walking. — What birds really walk? Why do so many birds hop, while on the ground, instead of walking? Do you know any

birds that prefer walking or running and seldom fly unless frightened? Is there any special adaptation of the feet in birds that spend most of the time on the ground? Compare the size and strength of the legs in birds that live on the ground with those of ordinary perching birds.

Food. — What does the bird eat? How does it discover this food? How does it secure it? Does it eat much or little? Has it any special time, or times, of day (or night) for feeding? Give particulars of the manner of feeding. Does it store food, or simply get what is needed for the present? If stored, how and where? Name any special adaptations for obtaining special kinds of food. How do birds drink?

Sociability. — Do birds live singly, in pairs, or in flocks? Do any birds that live in pairs during the breeding season ever flock at other seasons? Does the kind of bird you are studying mingle freely with other birds, or does it keep aloof? If they "meet by chance," are they shy? Do they quarrel? Are they inclined to be "quarrelsome"? Does one kind try to drive another away? Does the larger always defeat the smaller?

Nesting. — Does a bird habitually build in the same kind of place? Is the place selected with reference to enemies? To shelter? Do any prefer to rebuild in the same place? Of what material, or materials, is the nest made? How is this material obtained? How is it carried? How is it "handled" during the building? Do both sexes share in the nest building? Is the size of the nest, as seen from the outside, in keeping with the size of the bird? Is the space inside in proportion to the body? How many eggs are laid? Are they arranged in any definite way? Their color? Size? Shape? Is the shell thick or thin? How long from the time of beginning to "sit" till the young hatch out? Does the male ever "sit"? Does the male ever bring food to the female while she is "sitting"? What proportion of the eggs hatch? Do birds ever lay eggs in the nests of other birds? If so, do they lay them in nests of the same kind of bird? Are the

young able to get their own food as soon as they are hatched, or are they helpless? How fully feathered are they when hatched, and are the feathers the same in color and texture as in the parents? Which do they more nearly resemble, the adult male, or the female? On what are the young fed? Is food ever especially prepared for the young? Do both parents bring food? Do the young require much or little food? Are their eyes opened as soon as they are hatched? How long till they leave the nest? Till they can fly? Are they cared for after they leave the nest? Is the nest a "home"? Do the young return to the same spot? Do they ever occupy an old nest? Do they use any of the material of an old nest?

Migration. — Make a list of the birds that you see remaining here during the summer. Make another list of those that stay with us during the winter. Why do some of these birds go south in winter while others remain the year round? Is the blue jay any more warmly clad than the robin? Or is there some other reason than mere ability to "stand the cold" that leads one to stay while the other migrates? Do you see birds in the fall and spring that are not seen here either in winter or summer? How do you account for these facts? Make a list of birds that are seen only during fall and spring. Do birds migrate singly or in flocks? Or in pairs? Do you see in winter any birds that are not here in the summer?

Songs. — How many objects have birds in using the voice? How many distinct kinds of calls has this bird? Can this bird be said to sing? Do birds have a language?

Care of Feathers. — How do birds arrange their feathers and keep them in good condition?

Molting. — When do birds appear brightest and freshest? What makes the difference? Are all birds alike in these changes? Examine birds to find evidence of change.

Senses. — Can birds see well? Hear well? Experiment to test their senses.

Attitude. — Note closely the attitude assumed by the bird when at rest. In the case of tree birds observe whether they rest crosswise or lengthwise on a branch, whether erect or nearly horizontal, whether they prefer large branches or small ones, etc. Where and how do the different kinds of birds spend the night? What birds are astir at night?

Color. — Note the relation of a bird's color to its ordinary surroundings. What differences in the color and markings of the male and female? How do you account for these differences?

INDOOR STUDY OF BIRDS.

While the writer does not wish to encourage the caging of birds, it may sometimes be profitable to keep a bird in confinement for a time to study some of its habits that might escape observation in the free bird. A pigeon or canary will serve very well for this work. Suitable cages should be provided, and the bird should be well cared for. Try to make the bird feel as much at home as possible. Find what it prefers to eat, and learn its habits of eating and drinking. Learn how a bird winks. How does it sleep? How does it perch? Watch the breathing movements. Count the respirations for a minute when the bird is not especially excited. If possible, test the temperature of a bird by holding a clinical thermometer under its wing for a few minutes. (In this experiment be careful not to let the bird knock the thermometer out of your hands.) Close all the doors and windows and let the bird fly about the room to see how it flies. Study the actions of the wings and tail. Hold the bird by the body and when it flaps its wings learn what you can of their action. Can you determine definitely how the wing is moved in what we call the "down stroke"? At what angle is the wing held during this stroke? In the same way study the up stroke. Hold the bird above you and below you, with the head toward you and with the tail toward you, and note in which direction it fans the air most strongly.

In this work make use of canaries, parrots, and other of the commonly caged birds. Study the birds found in zoölogical gardens.

To what extent, and in what manner, do birds evince emotion such as anger, fear, etc.? Try bringing close together cages containing different kinds of birds. How much attention do they pay each other? Try placing a mirror close to a caged bird. Are birds affected by music? By harsh or loud noises?

If an owl can be captured alive, much can be learned from it. Give it a dead bird or mouse. See how it eats. Watch to see the pellets of hair and feathers that it ejects from the mouth after digesting the soft tissues. If a swimming bird can be kept, one may see how it swims. A tame duck may serve well for this. Drop a dead bird into a pail of water. Does it sink? Pluck the bird and again drop it into the water. Does it sink or float? Explain. How is it that birds keep so warm while flying in very cold air, as in winter when it is below zero? Do birds have parasites? Do they make effort to get rid of them? Can you help the birds get rid of them?

EXTERNAL FEATURES OF A BIRD.

How to handle a Bird. — Feathers are delicate structures and, if once crushed or broken, cannot be made over again. Never stroke feathers unless necessary. Above all, never draw a feather through the fingers. This ruins the texture forever. When needed smooth the feathers and deftly rearrange those that are displaced or twisted. When possible pick up a bird by the bill, not by the legs or tail. To take a bird in hand, pick it up by the bill and gently draw it into the other hand, back down. To lay it on the table, draw it lightly from the palm upon the table. To examine the tail feathers, hold the bird with its head toward you and with the thumb and fingers of the two hands take hold of the base of the tail and spread the feathers. Do not take hold of the tip of a feather, and it is seldom necessary to take hold of any part but the base of the quill. To examine the wing quills have the head of the bird toward you, and, passing the thumb and fingers by the front edge of the wing, hold the quills by their bases. Never pull a bird backward on the table by the legs or tail.

The Head.

1. The **beak** consists of the upper and lower **mandibles**; hold the pigeon's head with one hand, and with the other take hold of the tip of the upper mandible and see if it is movable.

2. Raise the upper eyelid, and look in the front angle of the eye for the third eyelid; seize the edge of this with the forceps, and pull it backward over the eye.

3. Brush forward the feathers below and back of the eye to find the **ear opening**; observe the peculiarities of the feathers which cover this opening.

4. Examine the **nostrils**; open the mouth and insert the head of a pin into the nostril, and probe, to discover its place of appearance in the mouth.

5. With the forceps pull forward the **tongue** for careful examination.

6. Just back of the tongue is the opening, the **glottis,** of the **windpipe,** or **trachea.**

7. The mouth continues backward to become the gullet.

The Legs.

1. Feel of the parts, beginning close to the body, to be sure to find the first division of the limb; this is the **thigh,** or "second joint."

2. Below this is the **tibia,** or "drumstick."

3. The next division is the **tarsus**; it is a consolidation of several bones that were distinct in the young bird; this part of the bird's leg, then, really corresponds to the tarsus and metatarsus of the human foot, or that part between the ankle and the toes. Where, then, is the true heel?

4. Bend and extend the **toes** to find how many bones there are in each.

5. The scales on the front of the tarsus are called **scutella**; hence the tarsus of the pigeon is said to be **scutellate** in front: the back of the tarsus of the pigeon is **reticulated.**

6. Bend the leg up close to the body in the position it has when the bird settles on its perch. What effect has this on the toes? Note the position of the toes when the leg is straightened.

The Tail.

1. Count the quills of the tail; spread the tail to see their mode of overlapping; make a diagram to show their mode of overlapping as seen from behind; compare the middle and outer tail feathers.

2. The feathers which lap over the base of the tail are the upper and lower **tail coverts.**

3. Raise the upper tail coverts to find the conical tip of the outlet of the oil gland; press the oil gland to get a drop of oil.

4. In front of the lower tail coverts is the **anus.**

The Wings.

1. Feel of the wing to make out the division into **arm, fore-arm,** and **hand.**

2. The foremost angle of the wing is called the **bend of the wing.** To what part of your arm does this bend of the wing correspond? Just outside of the bend of the wing find the **false wing,** a cluster of short quills, borne on the **thumb.**

3. The long **quills** borne on the hand are the **primaries**; count them. The quills on the forearm are the **secondaries**; count them. When quills are found on the arm, they are called **tertiaries.**

4. The shorter feathers which overlap these quills above and below are the upper and lower **wing coverts.**

5. Extend the wing; compare its upper and lower surfaces; observe the shape of the quills, and the way they overlap one another; put all these facts together and consider their effect in the down stroke of the wing. What is the result of this arrangement when the wing is moved quickly upward?

6. Extend the wing and hold it squarely in front of your face. Send a quick puff of breath squarely against the under surface of

the wing. What effect does this have on the individual feathers and the wing as a whole?

7. Repeat the experiment with the outer surface of the wing, noting carefully how each separate feather is acted on, and what is the effect on the wing itself. What is the effect of the wing on the air current in each of these experiments?

The Feathers.

1. Pull out one of the large wing quills and study its parts; the central axis is the **shaft**; the expanded part is the **vane**; the side branches of the shaft are the **barbs**, and the side branches of the barbs are the **barbules.** With a lens examine the upper and lower surfaces of the vane; then tear one of the barbs loose from the barbs in front of and behind it, and study it carefully; again watch closely while tearing two barbs apart, to see how the barbules are related to each other; now examine the vane of the same quill at the very beginning of the vane, near the end that was attached to the wing. What is the difference between the arrangement of the barbs in these two places? Observe the hole in the tip of the shaft; run the point of a dissecting-needle along the groove in the under surface of the shaft toward the base of the shaft. This should lead the point of the needle into another opening, communicating with the cavity of the shaft. Examine this region with a lens, and determine that the two sides of the vane meet at this point. Make drawings of a quill, as seen from above and below, showing all these points.

With sharp scissors cut across the feather in the middle of the vane. Look at the cut end; observe that the vane is attached to the **upper edges** of the shaft; compare the place of attachment of the vane to the shaft, with the place of attachment of the wing to the body. Cut part of the wider side of the vane at right angles to the barbs; with a lens, or a low power of the microscope, examine the edge of this cut. Make drawings showing these arrangements of the parts of the quill. What are the advantages of such arrangement?

2. Take one of the body feathers, and compare it with the quill. In what lies the chief difference?

3. Find a feather that is wholly composed of "down," if there be such; examine the "down" with a microscope.

4. Pick a small part of the breast, and study one of the fine, hairlike **pinfeathers**. How does it differ from the feathers already examined?

5. Take a primary feather that is in good condition and set it erect in the hole in the end of a trunk key. The hole should be deep enough to hold most of the length of the free end of the quill, but must not be so deep as to catch the vane and interfere with the free rotation of the feather. Instead of a key you may use a spool, piece of glass or metal tubing, or anything with a smooth hole of suitable depth and width. Now hold the feather, thus supported, vertically before your face and gently blow against it. How does the feather turn? In what position does it remain? Try this with the feather in different positions at the beginning of the experiment. Compare the results of this experiment with the observations made in blowing against the inside and outside of the wing, and explain the advantages of the shape, structure, arrangement, and mode of overlapping of the feathers. Try the breath on the secondary feathers as above directed. If you were using a quill for a pen, would it make any difference what kind of a feather you took? Would it make any difference whether it came from the right wing or the left wing?

6. Study the arrangement of the feathers; do feathers grow on all parts of the body? A fledgeling shows this point well. Push aside the feathers along the line of the ridge of the pigeon's breastbone and examine the skin; do feathers grow here? Look for other unfeathered areas. Note how the feathers overlap.

7. Pick the feathers from one side of the pigeon, just to the middle line; lay the bird on the feathered side, and make a drawing, showing (1) the outline of the feathers, and (2) the outline of the body within.

8. Pick off all the feathers of a pigeon or hen and weigh them

What is their weight? What fraction is this of the weight of the entire bird?

Use Jordan's *Manual of the Vertebrates* for finding the names of our native birds.

HOW TO PREPARE A BIRD SKIN.

Materials Needed. — 1. A freshly killed bird, in good condition. 2. Arsenic, or arsenic and powdered alum in equal parts. 3. Cotton. 4. Several sheets of paper; stiffer paper than newspaper is preferred. 5. A plate. 6. Scissors. 7. Knife (scalpel, if possible). 8. Forceps. 9. String. 10. Corn meal, to sprinkle on for absorbing blood or other liquid escaping.

Process. — First make a wad of cotton and with the forceps push it into the throat. This is to keep moisture from escaping and soiling the feathers. Do the same with the anal opening. Break both wings as close to the body as possible. Now lay the bird on its back, with the head toward your left. Part the feathers along the breast and abdomen. Hold them apart with the thumb and fingers of the left hand, while with the scalpel you cut through the skin, beginning at the center of the breast and going straight back to the anus. Here make a fork in the cut and go around the anal opening. With forceps hold up the edge of the skin while loosening it with the handle of the scalpel. Be careful during the whole process to keep the feathers turned back so they will not be soiled by coming in contact with moist tissues. Sprinkle with corn meal to absorb moisture. Loosen the skin on one side down to the thigh, and around the knee. Then with the thumb and finger take hold of the tarso-metatarsal joint (heel) and push the knee out, at the same time pressing the skin back so as to expose the knee. Run one blade of the scissors under the bend of the knee and cut through the joint (cut close to the joint of the scissors to avoid straining them). Cut through the remaining flesh, being careful not to cut the skin. Take hold of the leg with thumb and fingers of one hand, thus suspending the whole body. With the thumb and fingers of the other hand carefully scrape the skin away from

the flesh, using the thumb and finger nails. It will not do to pull on the skin, as it is too tender. On reaching the heel remove all the flesh, leaving the bone. Now pour about half a teacupful of arsenic on a plate. Hold the everted leg over the plate and apply arsenic thoroughly to the skin and the bone. Take hold of the toes and pull the skin right side out again. Repeat this with the other side. After loosening the skin well back on the sides, lift the bird, rest the front end of the breast on the table, and turn the tail toward the back. Cut through the bones supporting the tail close to the bases of the tail feathers, but care must be taken not to loosen them. Over the rump there is almost no flesh and the skin adheres to the bone. Especial care must be taken here not to tear the skin.

Continue toward the head, turning the skin wrong side out. From this point on, it is very convenient to have a suspended hook by which to hang the bird so you can use both hands in skinning. Otherwise hold the body just in front of the hips. If pressure is applied to the abdomen its soft contents may be forced out. When the shoulders are reached, skin as far as the elbow and cut off the wings where the bones were broken. When the head is reached great care must be exercised. Proceed slowly, pressing the skin loose with the nails. At the ear, the thin sac, lining the ear down to the drum, must be pulled out. In skinning past the eyes be sure not to cut the eyelids. Continue to the base of the bill. Sever the neck close to the skull, cut out the base of the skull and remove the brain by scooping it out with the handle of the scalpel. Remove the eyes, tongue, and all soft tissues on the head. Now return to the wings and cut away all the muscle from the humerus. It is not safe to try to skin beyond the elbow because it would loosen the secondaries; but the fleshy inner surface of the forearm may be uncovered, part of the muscle removed, and arsenic pushed in to poison what remains. Remove any particles of muscle or fat still adhering to the skin. Now lay the skin, still turned inside out, on the plate of arsenic. Roll it over and over in the arsenic and thoroughly rub the preservative on every part of the skin, skull, and other bones, especially at the wings, legs,

and tail. Roll balls of cotton and place in the eye sockets. Now proceed to turn the skin. Placing the thumbs at the base of the skull, use as many fingers as can work in pulling (or rather rolling) the skin back over the head, the thumbs meanwhile pushing. Care and *patience* must be used here, otherwise a good skin may be ruined. When the skin has been turned back over the head it is easy to grasp the bill, and the entire skin is again outside out. It will probably look rather dilapidated, but do not be discouraged. Shake it, holding by the bill, to get rid of the loose powder and to rearrange the feathers. With forceps or scalpel handle arrange the feathers where needed. Lay the skin on its back. Make a slender roll of cotton for a neck, and with the forceps insert it so it will reach the base of the skull. Next make a body of cotton (you have the model before you). In inserting the body, see that the feathers around the edge of the cut are not turned in. Draw together the edges of the ventral cut; it is not necessary to sew, but the feathers should be made to overlap naturally. Cross the feet and tie them together, thus crossed. Make a stiff paper cylinder, and tie or pin it so it will not spread. Slip the skin in, head first of course, taking care that the feathers overlap properly. Especial attention needs to be paid to the region of the shoulders. Attach a label, with the name of the bird, sex, date, locality, and your name. Lay away in a safe, dry place for at least a week, before removing from the cylinder. Birds may be mounted on a board with wings spread.

DISSECTION OF THE PIGEON.

In dissecting the pigeon place it on a smooth board about twelve inches wide and eighteen inches long. If a sheet of paper be fastened to the board by thumb tacks, the board may be kept clean for repeated use. In dissecting it is better to turn the board than to turn the specimen on the board. The wings and legs or any flaps of muscle may be stretched out and tacked down to suit convenience at different stages of the work.

Pluck the pigeon before dissecting it; dipping the bird in hot water makes this easier.

1. Insert a large tube into the mouth and inflate the **crop**, compressing the neck to prevent the escape of the air. Note the shape of the crop.

2. Beginning at the posterior end of the breastbone, cut through the skin along the line of the ridge, or keel, of this bone, and loosen the skin on each side, continuing forward over the crop, being careful not to tear the crop; again inflate the crop, and examine it more fully. Observe the fine lines running crosswise and lengthwise in the walls of the crop; these are the muscle fibers, transverse and longitudinal.

3. Loosen the crop from the front of the breast and from the neck. Find the windpipe, or **trachea**, with its white rings of cartilage.

4. On each side of the neck is the **jugular vein**. If it does not show distinctly, let the bird's head and neck hang over the edge of the table, and the vein will soon fill with blood.

5. Close to the jugular vein is a white cord, the **vagus nerve.**

6. Insert the tube into the glottis, and inflate; observe the swelling of the whole body, and the inflation of the thin-walled **air sacs** in the hollow in front of the breastbone.

7. Break the bone of the upper arm, the **humerus**; cut through the skin and muscles, and push out through this opening the end of the bone next to the body; note that it is hollow; slip one end of a rubber tube over the end of the bone, and inflate; what is the result of this experiment? Keeping another tube connected with the windpipe, determine whether air can be sent in through the windpipe and out of the humerus, and *vice versa*.

8. Slit the skin back over the abdomen to the anus, loosen it well back on each side, and cut through the abdominal wall just behind the breastbone; inflate once more, and observe the **abdominal air sacs.**

9. Cut down into the muscle of the breast, close alongside the ridge (keel) of the breastbone, and around the outer border of the breastbone; thus loosen and raise a great flap of muscle, **the pectoralis major.** Note the nerve and blood tubes entering

its inner surface; separate it from a smaller muscle lying under it, which will be known by the glistening appearance of the muscle sheath; sever the attachment of the pectoralis major to the breastbone, and all other organs except at the extreme front end; here the muscle narrows into a tough white cord, or **tendon**; trace this tendon to its attachment to the bone of the arm; now lay the pigeon on its back in one hand, and pull this muscle backward, noting the effect on the wing. In like manner loosen all the posterior attachments of the **subclavian** muscle which was covered by the pectoralis major, lying in the angle between the keel of the breastbone and the body of the breastbone; prove its action, this time holding the pigeon right side up. Compare these two muscles in size, and in the amount of work they have to do. The hinder attachment of each of these muscles is called its **origin**; and the place of attachment of the tendon to the wing bone is the **insertion**. Cut through the body wall around the margin of the breastbone, through the ribs, coracoid bones, and wishbone, and entirely remove the breastbone.

10. Covering a considerable part of the abdominal organs is the reddish brown **liver**.

11. Lift the liver and disclose, at the left of the body cavity, a hard mass, the **gizzard**. Slit the abdominal wall in the middle line back to the anus, push aside any fat that may cover the internal organs, and turn the gizzard to the left of the bird to find where the intestine arises from it; trace the intestine from the gizzard backward.

12. The part of the intestine nearest to the gizzard is the **duodenum**.

13. In a long loop formed by the duodenum is a pinkish organ, the **pancreas**.

14. Trace the intestine, tearing away the fat and the thin walls of the abdominal air sacs, observing that it is held in place by a thin, transparent membrane, the **mesentery**.

15. The intestine has two short side branches, the **ceca**.

16. Just before the intestine ends, it widens, forming **the cloaca.**

17. Turn the gizzard to the right of the bird; entering it from the front, find a mottled, bulging tube, the **glandular stomach**; pull the crop forward, to shew the connection between it and the glandular stomach. To the right of the glandular stomach is the small, red spleen; pull the gizzard backward, and cut off the glandular stomach as far forward as possible; remove the gizzard and intestines. Note the relations of the tubes which enter and leave the gizzard; open the gizzard, observing the thick outer muscular coat, from which the gizzard is sometimes called the **muscular stomach.** Note also its tough lining; examine the contents of the gizzard; why does the gizzard have such a thick coat of muscle? Do all birds have this kind of gizzard?

18. In front of the liver is the **heart**, in a thin sac, the **pericardium.** Cut into its posterior wall, and turn the heart forward, to see the dark vein, the **postcaval vein**, running to it from the liver; pull the heart backward, to see the whitish **arteries** running forward from it. The main artery runs forward, and turns to the right before going backward, while in man the corresponding artery turns to the left. Prick a hole in one of the large veins near the heart; insert the point of a blowpipe, and inflate the heart; its red, conical part is composed of the **ventricles**; the dark base is made up of the two **auricles.** Tie a thread around the veins at the anterior and posterior borders of the liver, and cut this organ away.

19. On each side are the pink lungs. Pick away the thin membranes bordering the outer hinder borders of the lungs; look for holes through which the lungs communicate with the abdominal air sacs; look for the trachea. Remove the lungs, not failing to see how closely they are attached to the back, being indented by the ribs.

20. In the hinder part of the body cavity are the dark-colored, irregular **kidneys.** Tear them away, observing how

they are composed of several lobes, which fit into the hollows of the **pelvis**. After removing the kidneys, observe the white nerves extending outward from the sides of the spinal column to pass to the thighs.

21. In front of the kidneys are the two white oval **spermaries**, in the male ; in the female, the **ovary**, often showing many eggs in different stages of development. The kidneys and reproductive organs send tubes to the cloaca ; the tube which conveys the eggs from the ovary to the cloaca is the **oviduct**.

22. Remove the heart, cut off the auricles, and look down into the ventricles ; cut across the middle of the ventricles, and make a drawing of this cross section.

23. Observe the fold of skin extending across the angle between the arm and forearm ; dissect away the skin, and find a membrane within the skin fold.

24. Observe the muscles connecting the hinder edge of the breastbone and the pelvis (which were cut through in opening the abdomen) ; these are the abdominal muscles. How does the bird perform the act of breathing ? Compare the bird, snake, frog, and man, in their modes of breathing.

25. Bend the leg up close to the body, to the position of perching ; what effect does this bending of the leg have on the toes ? How does the bird stay securely on the perch when asleep ? Dissect the leg to find the mechanism by which the toes are clenched as the leg is bent.

26. Dissect out the tongue, and compare it with the tongue of the snake.

27. Clean away as much as possible of the soft tissues, and keep the skeleton for later study.

THE BRAIN OF THE PIGEON.

Cut away the top of the skull with a sharp knife, using great care not to injure the soft brain, and make out the following parts : —

1. In front, the large **cerebrum**, consisting of two **hemispheres**, which are separated by a deep groove.

2. Behind the cerebrum is the undivided **cerebellum.**

3. Running backward from the under side of the cerebellum is the **spinal cord**; trace it back into the backbone. Make drawings of the brain, as seen from above and as seen from the side.

THE SKELETON OF THE PIGEON.

Notice the lightness of the whole skeleton. What part of the pigeon's weight is bone? Compare the eye cavity with that of man. The lower jaw does not join the skull directly, as in man, but is joined to an irregular bone, which, in turn, joins the skull. This is the **quadrate bone.** The hole by which the spinal cord leaves the brain cavity is the **occipital foramen**; in front of this foramen is a little, rounded projection, the **occipital condyle.** Observe how this condyle fits into a cavity in the first vertebra of the neck. Count the vertebræ of the neck, or **cervical vertebræ.** Observe the consolidation of the vertebræ in the back; note the joint in each rib, and the arrangement for bracing the ribs together. Press the breastbone alternately toward the back and away from it, meanwhile watching the joints in the ribs.

The "wishbone" corresponds to the two "collar bones" of man. Alongside the two branches of the wishbone are the coracoid bones; what especial need of such bones in this place? In the wing find, in the arm, the **humerus**; in the forearm, the **ulna** and **radius.** The **hand** has only part of the fingers developed; a little bone, representing the thumb, is present (which bore the feathers of the "false wing"). In the thigh is the **femur**; in the leg is the **tibia**; and alongside it, the small **fibula.** The bone above the foot represents the consolidated bones of the human ankle and foot as far as the toes. What evidence is there of such consolidation?

THE HEN'S EGG.

So place a hen's egg in a basin of water that it cannot roll, mark the upper side plainly, and boil it hard; keep track of the side that was uppermost.

1. Crack the shell, and pick it away; put a piece of it in strong vinegar, or other acid. Of what is the shell made?

2. Note the thin membrane lining the shell.

3. Does the egg completely fill the shell? Where is the **air space**? Does the lining membrane, in this region, adhere to the shell or to the "white"? How can a fresh egg be distinguished, without breaking? Does a fresh egg, in water, lie in the same position as when on a table? What is the use of this air space?

4. How is the yolk situated in the white? How in reference to the position during boiling? Compare a number of eggs, to see if there is any regularity about this.

5. Note the round spot on the yolk, where it comes nearest to the surface. This is the **germ spot,** in which the chick begins to form.

6. With a sharp knife, split the egg lengthwise. Is the white alike throughout? Is the yolk alike throughout? Has the yolk a coat? Cut and tear these parts to make out their structure, if they have any definite structure.

7. Boil an egg hard, as before; mark a line lengthwise around the egg, passing through the point that was uppermost while boiling; carefully break away the shell on one side, and with a clean cut remove this half of the white and yolk; place the other half in the position it had while cooking; make a drawing of this section, using different colors to show the shell, shell membrane, air space, white, yolk, germ spot, etc.

8. Prop an egg on end, and boil in this position. Is the yolk in a different position in consequence? The white of the egg has interlacing fibers and partitions which keep the mass together; the white cannot be mixed with water till these membranes are cut or broken; hence an egg, to be eaten raw, should be whipped to break these membranes. The white is not a part of the true egg. In dissecting a bird, the eggs, of various sizes, according to their stages of development, may be found in the ovary. At this time the egg consists of the yolk, with a thin coat; the white is deposited around this later, during its descent through the oviduct;

the shell is last formed, and is absent in the case of most animals. In the development of birds all their nourishment, before hatching, must be stored in the egg; hence its large size.

9. Set a hen on a dozen eggs; mark the date; open and examine an egg each day; if the egg was fertilized, the cells of the germ spot multiply by division, and soon take definite arrangement; at the end of twenty-four hours the backbone is outlined; during the second day the brain begins to develop, and the heart appears; on the fourth day the legs and wings make their appearance as flattened buds; during the first few days it is hard to say whether the embryo was that of a bird, a reptile, or a mammal; after this, the characters peculiar to birds become evident, the feathers begin to develop, and, later, the particular kind of bird may be recognized.

Egg-laying animals are called **oviparous.** If the young develop within the body of the parent, receiving nourishment from the blood of the parent, the animal is said to be **viviparous**; "or, the young may complete its development while the egg remains in the interior of the body of the parent, but quite free and unconnected with it, as in those vertebrates which are termed **ovoviviparous.**"

The study of **development** is called **embryology.**

Topics for Reports. — Ostrich Farming. Origin of our Domestic Fowls. Origin of the Domestic Pigeon. Varieties of Pigeons. Game Birds. The Guinea Fowl. The Turkey. Hawking. Carrion-eating Birds. Birds whose Plumage is used for Ornament. Birds and Millinery. Laws for Bird Protection. History of the English Sparrow. The "American" Eagle. The Fishhawk. The Whip-poor-will. Introduction of New Game Birds. The Road Runner. The Mocking Bird. The Water Ouzel. Hawks and Owls.

Read *American Natural History*, Hornaday.

CHAPTER XII

MAMMALIA.

THE RABBIT.

Field Study.

1. Learn where to look for rabbits at different seasons. Keep in mind that they are timid creatures and seek shelter, and that they prefer to be near a good supply of food.

2. In what kind of places are rabbits usually found in warm weather? Look in tufts of grass along hedges and fence corners. Do rabbits seek more sheltered places in winter? Is this on account of cold? Or for concealment? The smoothed and sometimes slightly hollowed place in which a rabbit squats is called its "form." Is this form equally exposed on all sides? Can it enter and leave in any direction? Has the direction in which it is headed any relation to the wind? In what position does it rest? Are the ears erect or laid back while it sits in its form? Does a rabbit leave its form in the daytime, if undisturbed? Does it sleep during the day? Are the eyes open or shut while it sits in its form in daytime? As you quietly approach the rabbit squatting in its form, does it seem aware of your presence? Does it ever turn the head to see you? Does it need to turn the head to see you? Can a squatting rabbit see an object in any direction without turning its head? Stand near a rabbit in its form and watch its eye. Does it wink? How much of the time is a rabbit in its form? How much of the time out of it? Find a rabbit in your neighborhood and frequently visit it to become as well acquainted with it as possible. On moonlight nights visit a form that you have lately

found occupied. Is "Brer Rabbit" at home? Are rabbits sociable? Do they associate with each other more at one season than at another? Do they seem to have any special means of communicating with each other? Do they ever give signals of danger? Does one ever call another to share food that it has found? Do they ever aid each other in any danger or injury? Has the rabbit a voice? If so, on what occasions is it used? How do rabbits protect themselves from cold? How does the squatting position economize heat? Do rabbits ever stretch out and lie at full length? Or are they always bunched up when resting? In what situations do you find rabbits in warm weather? In very cold weather? In dry weather? After heavy rains? Do rabbits ever burrow? Do they hide in holes? What are the effects of substituting barbed wire fences for rail fences and hedges? What is the effect of grubbing out bushes in clearing land for cultivation? How does the cultivation of farm and garden crops affect rabbits? Is the number of rabbits ordinarily increased or diminished in "settled" districts?

3. Study carefully the rabbit's modes of locomotion, the slow hopping as well as the running. Study the tracks and be sure you can tell by which foot each track is made, and how the legs are moved. Can you tell by the tracks whether or not the rabbit was frightened? How far can a rabbit jump? Are the front and hind tracks farther apart when running than when hopping? Can a rabbit run far without stopping? Follow a frightened rabbit; does it run far in a straight line? Can you stop a running rabbit by whistling? Do rabbits ever zigzag when running away? If so, why? Are rabbits long-winded? Compare a rabbit and a greyhound in this respect. What reasons for the difference? Can a rabbit swim? Does it often take to water?

4. What evidences do you find in fields and among bushes as to the rabbit's food? When does it eat? Does it need much or little food? Does it usually go far from its form for food?

Does the kind of food vary much with the season? Does it need to make much effort to get its food? Do rabbits drink water? Look along creeks and around springs for evidences of their visits. Is it clear that they come to such places to drink? Does the amount of water in their food make any difference in the amount of water that they take as such? Do they need the same amount of water at different seasons? What reasons for these differences? Do they ever suffer for water in severe winter weather, when streams are frozen over?

5. What harm is done by rabbits? Do they do any good? What means are employed to keep them from doing damage? What means to kill them off?

6. What are the enemies of rabbits? In what different ways do they avoid or escape enemies? Is there any advantage in having the exposed part of the tail so white and conspicuous? What kind of shelter does a rabbit seem to prefer when pursued by dogs? Do rabbits ever "double" on their tracks? Or resort to other tricks to escape pursuit? What is meant by "circling"?

7. In spring and early summer look for the nests containing young rabbits. They are not conspicuous, being pocketlike depressions lined with fur, and narrowed at the opening, which is at the level of the surface. If a nest is found, watch it closely day and night. If you have a dog, be careful not to allow him to accompany you, for even if he does not disturb the nest while with you, he may return and kill the young. Does the mother stay with the young? If not, does she remain near? When and how often does she visit the young, and how long does she stay with them? Do rabbits have more than one litter in a year? How many in a litter? Is their natural rate of increase slow or rapid as compared with most mammals? Are the young of the same color as the adults? Are there any peculiar markings? How long does it take a young rabbit to reach full size? Are young rabbits as speedy or as cunning in escaping enemies as the old ones?

HOME STUDY OF RABBITS.

1. For this study use a wild rabbit caged, a tame rabbit, or a Belgian hare. Study many of the points to which attention has been called in the suggestions for the study of wild rabbits in their homes, such as the modes of hopping, jumping, running, modes of moving the feet, the tracks, etc. Study also the various attitudes of rest and motion, of timidity, of effort at concealment, of hunger, the use of the ears and eyes. Do they give any signals when alarmed? Do tame rabbits recognize dogs as enemies? After an alarm do rabbits soon become quiet, or does fright have a more lasting effect? Has a rabbit any means of defense against enemies? Are the claws ever used when it is attacked by a dog? Or when it is seized by a man, as when pulled out of a brush heap or a hole? Do rabbits ever fight each other?

2. Find what food the rabbits prefer. Does a rabbit eat much, relatively? Does it eat rapidly or slowly? Watch the process of eating. How do the jaws move? What is the use of the "harelip"? If possible, in this connection, get a well-cleaned rabbit's skull, and study the teeth and the hinge by which the jaw joins the skull. Why is there a vacant space between the gnawing teeth and the grinding teeth? How are the front teeth kept sharp? How do the ridges run on the grinding surfaces of the back teeth? Why is this so?

3. Is a rabbit's eye large or small, in proportion to its size? Is its sense of sight keen? Test this in various ways. What is the shape of the pupil of the eye? Is it relatively large or small? Does it vary with the amount of light? Do you ever see color in the pupil? If so, in what situations? Is the iris of the same color in all rabbits? Compare wild and tame rabbits in this respect. Test a rabbit's sense of hearing. Is the fact that a wild rabbit often sits motionless in its form, sometimes till actually kicked out, any proof that it did not hear or see the hunter? What is it probably thinking in such a situation?

Test the sense of smell in rabbits. Does it use this sense in judging food? Has it a keen sense of taste? Try to test the sense of taste without also bringing into use the sense of smell. Test the sense of touch. What is the use of the "whiskers"? Do you think a rabbit possesses any sense that you do not have, or lacks any that you have?

4. Are rabbits cleanly in their habits? Do they wash their paws and faces as do cats? Do rabbits shed hair? Do they change their color during the year? Do rabbits have parasites? If so, what kinds? Do they do anything to get rid of them? Can you do anything for such troubles? Are rabbits especially subject to any diseases? If so, what are they, and what can you do to prevent disease, or to cure it if it has become established?

EXTERNAL FEATURES OF THE RABBIT.

1. Note the shape and proportions of the body. The anterior part of the body, distinguished by the ribs, is the **chest**, or **thorax**; the soft-walled, posterior part is the **abdomen**. Note the relative size of the fore and hind limbs. Are the soles of the feet bare or hairy? How many toes has each foot? Are there claws? Are they weak or strong? How do they differ from those of a cat? In the hind limb how much belongs to the foot?

2. How many kinds of hair do you find on a rabbit? The short hairs, making the most of the coat, are the **fur**. How do the hairs of the fur differ from the other hairs? Press hair and fur aside till you can see the skin; is the color the same in the deeper parts as near the outside? Pull out hairs of different sorts; has an individual hair the same color from end to end? Are the different hairs of the same thickness and strength? Are they all rooted to the same depth in the skin? Are the hairs glossy or dull-surfaced? Do they seem oily? Do they become wet easily? Compare them with the hairs of a mink or muskrat in these respects. Examine different hairs under a microscope

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What are the qualities that make some kinds of hair or fur preferable to others for making furs, felts, and fabrics? What are some of the chief articles made of fur after it is separated from the skin?

3. Examine the eyes and eyelids. Can you find a third eyelid? Is it useful?

4. Examine the mouth. What is the use of the "hare-lip"? What is the shape of the nostrils? Look closely at the inside of the cheek. How many front teeth are there and how are they arranged? Are they alike in size and color? Have any of them any peculiar markings? Examine the tongue and palate.

5. Examine the ears. Hold one of them up toward a good light.

6. Examine the tail. What is its usual position? Can you make it stay in any other position? Is its color uniform? Of what use is it?

Use Jordan's *Manual of the Vertebrates* in finding the names of all the mammals met with in your neighborhood.

DISSECTION OF THE RABBIT.

The rabbit should be dissected on a board eighteen inches long by twelve inches wide. This should be covered with heavy manilla or straw paper, fastened down by tacks. The specimen should be a freshly killed, uninjured one, those obtained from the markets being usually so mutilated as to be unfit for this work.

1. Lay the rabbit on its back, stretch out the front and hind limbs and tack firmly through the feet. Slit the skin in the middle line from the base of the neck to the pelvis and strip it well back along the sides. Compare the walls of the thorax and abdomen. With forceps pinch up a fold of the wall of the abdomen, and with scissors cut through the wall in the middle line. In all this work be careful that the lower point of the scissors does not injure anything within. Cut forward in the middle line to the breastbone.

When the chest is first opened, look in to see the position of the heart. The attachment along the inside of the breastbone must be cut close to the bone.

When the breastbone is reached, let the cut fork to each side along the line where the bony part of the ribs ends and the cartilaginous part begins. At the anterior end cut across the breastbone and entirely remove it. Extend the slit in the abdominal wall to the pelvis. Make slits outward in the middle of each side of the abdominal wall; turn the flaps outward, pinning them down if necessary. There are now disclosed the two parts of the **body cavity**, the **chest cavity**, or **thoracic cavity**, containing the heart and lungs, and the **abdominal cavity**, containing the digestive organs. Between these two cavities, and the sole partition separating them, is the thin muscular **diaphragm**. Examine the diaphragm from the anterior side. Can you see that its central part is thin and nearly transparent? This is the tendinous part of the diaphragm. Note the shape of the diaphragm as seen from the front. Gently press the liver backward to see the posterior surface of the diaphragm. Take hold of the diaphragm with thumb and finger on its opposite surfaces to learn its thinness, its smoothness and flexibility. Is the diaphragm flat or arched? How is it arched?

The Organs of the Abdominal Cavity.

1. Observe that the ventral wall of the abdomen is composed of muscle. Its smooth lining is the **peritoneum**. Feel of it.

2. Study the abdominal organs in their natural position. Filling most of the space of the abdominal cavity is the coiled intestine; next to the diaphragm is the dark-colored liver; back of the liver, and partly covered by it, is the stomach; and in the posterior part of the abdomen is the bladder.

3. Pull the intestine backward, and make out the shape, size, position, and color of the **stomach**. Observe how the liver and stomach fit together; push the liver forward, and turn the stomach back to find a white tube entering its anterior **surface**;

this is the gullet, or **esophagus**. Just back of the stomach is a small, red body, the **spleen.**

4. Find now the connection between the stomach and intestine. Make a drawing of the stomach, showing its shape and the connections with the gullet and intestine.

5. Trace the intestine; that part which forms a long loop near the stomach is the **duodenum**. Within this loop is an irregular, fatty-looking mass, the **pancreas**. Find the **pancreatic duct** entering the intestine. This is more easily found in the dog.

6. Observe that the intestine is held by a thin membrane in which are branching blood tubes; this is the **mesentery**; find its supporting attachment. In tracing its course drag the intestine out of the abdominal cavity, but do not tear the mesentery.

7. The large, greenish side branch of the intestine is the **cecum**. All the intestine from the stomach to the entrance of the cecum is the **small intestine**; that part of the intestine posterior to the entrance of the cecum is the **large intestine.**

8. In handling the liver remember that it is very delicate and easily torn, also that it contains much blood, and if torn is likely to bleed enough to interfere with the dissection. Do not touch the liver with any sharp instrument; even the finger nails may tear it unless one is careful. Pull back the liver to see how snugly it fits against the diaphragm. Are the two attached to each other? Note the divisions, or **lobes**, of the liver. Tip the liver up and forward to see the stomach, and how the organs fit each other. On the posterior surface of the liver find the dark **bile sac**. If its duct to the intestine is not readily seen, press on the sac and some of the bile may be forced along the tube, thus showing its course. Later snip a small hole in the bile duct, insert a bristle tipped with sealing wax, and find where the duct enters the intestine.

9. Tie the gullet in two places half an inch apart and cut through between them. Do the same with the hinder part of the

large intestine, the **rectum**, and sever it. Remove the stomach and intestines, carefully cutting the mesentery along its whole attachment to the intestine, and uncoil the latter. How many times is the length of the body, including the head, contained in the length of the intestine? Compare the lengths of the small intestine, cecum, and large intestine. Cut out about an inch of the small intestine in the middle of its course, slit it open lengthwise, wash it thoroughly, and examine, under water, its inner surface with a lens, to see the threadlike projections, or **villi**. In the same way examine a piece of the large intestine. These points may be made out in the intestine of a dog, or from specimens of the calf's intestine obtained from the butcher. Tie the postcaval vein just in front of the diaphragm and just back of the liver; cut away and remove the liver.

10. Observe the two bean-shaped kidneys attached to the dorsal wall of the abdomen. They are covered by a thin layer of membrane, the peritoneum, which lines the whole of the abdominal cavity, and turns downward to form the mesentery, which, like a sling, holds the intestine in place; the mesentery also covers, and almost completely surrounds, the stomach as well as the liver. An artery, a branch of the aorta, extends into each kidney, and from each kidney there runs a vein to join the large postcaval vein. There is also a tube, the **ureter,** from each kidney, running back to the urinary bladder.

The Heart and Lungs in Natural Position.

1. It should be noted that the heart and lungs collapse when the chest is opened, and that they do not now show their natural size. Slit the skin along the middle of the throat and find the windpipe. Cut a slit in it lengthwise. Insert a tube, connected by rubber tubing with a pair of bellows; or inflate by the breath. The lungs may be swelled to their natural size, filling the chest. This will also show the natural relations of the heart and lungs. Note how the lungs nearly surround the heart. Compare the

color of the lungs when inflated with the color when collapsed. Notice the subdivisions, or **lobes**, of the lungs.

2. In another rabbit, later, open the abdominal cavity without injuring the thorax. Pull back the liver, and the pink lungs will show through the thin central part of the diaphragm. Keeping the eye fixed on the lung, prick a hole through the diaphragm near one side, and note the collapse of the lung. Is the lung of the other side affected by this operation? Open the chest and note the thin partition separating the two sides of the chest. This partition, the **mediastinum**, is a double membrane, and the heart lies between its two layers. The following study of the heart and lungs may be made with the heart and lungs of the rabbit; but if the same organs of a pig, sheep, or calf can be obtained, it will be better to use them on account of their greater size.

Topics for Reports. — The Fur-bearing Animals, such as the Beaver, Otter, Sable, Mink, Muskrat, etc., with Accounts of their Homes, Habits, and the Modes of trapping them. The Hudson Bay Company. The Native Ruminants of North America, such as the Musk Ox, Caribou, Moose, Elk, Deer, Sheep, Goats, and Antelope. The Kinds of Bears native to North America. The Mountain Lion. The Coyote. The Timber Wolf. The Wild Cats. Prairie Dogs. The Weasel. The Badger. Jack Rabbits. Porcupines. The Buffalo.

Read *American Natural History*, Hornaday.

CHAPTER XIII.

MAMMALIA (*Continued*).

DISSECTION OF THE HEART AND LUNGS.

THE heart and lungs of a sheep, pig, or calf are better to study on account of their greater size.

1. Hold up the mass by the windpipe, with the heart away from you. The end now uppermost is the **anterior** end, that below is the **posterior** end; the lung to your right is the **right** lung, the one to your left is the **left** lung; the surface nearest you is the **dorsal surface**, and that opposite is the **ventral surface**.

2. Observe the windpipe, or **trachea**, with the stiff rings of gristle, or **cartilage**. The thick part of the anterior end is the **larynx.**

3. Running along the dorsal surface of the windpipe is a soft red tube, the **gullet** or **esophagus**. At about the middle of the windpipe separate the gullet and windpipe for three or four inches. Note that next to the gullet the windpipe is soft and yielding, where the gaps of the C-shaped cartilages are filled with muscular and elastic tissue. Make a slit two inches long in this soft membrane.

4. Inflate the lungs as follows: Take a wooden faucet, slip the small end of the faucet into the slit just made in the windpipe, and hold or tie firmly, but do not cut off either gullet or windpipe. Inflate through the spout, then shut off the air; if the lungs have not been punctured they should now remain distended. In holding up the lungs, *take hold of the windpipe* above where *the faucet* enters, and hold in such a way as to pull the windpipe up and at the same time press the faucet down. If this is done, it will not be necessary to tie the faucet in. Note

(*a*) the conical shape of the whole; compare this with the chest cavity, as shown in a skeleton; (*b*) how the lungs nearly surround the heart; (*c*) the concave posterior surface of the lungs where they fitted the convex anterior surface of the diaphragm; (*d*) the groove between the dorsal surfaces of the lungs in which the spinal column fitted; (*e*) the smooth, undivided dorsal surface of the lungs, and their division ventrally into **lobes**; (*f*) the relative lengths of the dorsal and ventral surfaces of the lungs. The anterior end of the lung is the **apex**; the posterior end is the **base**. Open the valve of the faucet. What makes the air go out? Again inflate. Does it require effort to do so? Why? Cut off the end of one lobe and again inflate. Does the air escape? Throw a piece of lung on water. Pinch a piece of lung, holding it near the ear. The smooth, moist, glistening membrane covering the lung is the **pleura**.

5. Observe a large whitish or yellowish tube running in the groove between the dorsal surfaces of the two lungs. It is usually covered with fat. It may have been cut off short, so that its open end is easily seen near the windpipe. This is the main artery, the **aorta**. Take hold of its free end and separate it from its attachment to the other tissues, cutting close to it with the scissors, so far as where it arches over the root of the left lung. Now turn the free end forward.

6. Find where the gullet is cut off posteriorly; slit it open for an inch or two, and note its whitish lining, the **mucous coat**. The thick red coat is the **muscular coat**; it has an inner layer of circularly arranged muscular fibers and an outer longitudinal layer. Beginning posteriorly, separate the gullet from the windpipe, cut off the windpipe about the middle, and entirely remove the gullet and larynx.

7. Examine the windpipe; insert a finger, and stretch it; note its C-shaped cartilages. Its lining is a **mucous membrane**.

8. Lay the heart and lungs on their ventral surface, with the posterior end near you. Using the handle of the scalpel as a chisel, clear away any tissue covering the windpipe, and trace it

to the lungs; its branches are the **bronchi.** How many bronchi are there? Here are often found small, oval, brownish masses, the **lymphatic glands**, embedded in connective tissues. Scrape these loose with the scalpel handle.

9. Lay the lungs on their dorsal surface, with the anterior ends toward you. Note how easily the heart may be moved about in its case, the **pericardium**. Slit the pericardium along its ventral side, and note the smoothness of its lining and of the surface of the heart. Observe the **pericardial fluid**.

10. Carefully compare the right and left sides of the heart. Running obliquely across the surface of the heart is a groove in which are blood tubes, often covered with fat. The part at the right of the groove is the **right ventricle**; at the left is the **left ventricle.**

11. At the base (anterior end) of the heart on each side are the right and left **auricles.**

12. Tip up and toward you the apex of the heart. Compare its width and thickness; compare the ventral and dorsal surfaces as to length, convexity, etc. Press the two ventricles, and compare them in firmness.

13. Turn the heart to the left, and examine the right auricle; find a large, flabby, red tube entering its anterior surface, the **precaval vein.** Prick a small hole in it, and insert the blowpipe; hold firmly around the opening and inflate. This shows the outline of the right auricle. Meanwhile, watch closely the dorsal part of the auricle; the **postcaval vein** should now be discovered entering the auricle from the posterior region. Look for it outside, and on the dorsal side of the pericardium, where it runs anteriorly from the diaphragm.

14. Turn the heart to the right, and observe a large, light-colored tube arising from the base of the right ventricle between the two auricles; this is the **pulmonary artery**. Again turn the heart to the left, and raise the right auricle; find the **aorta** arising from the center of the base of the heart. Carefully separate the aorta from the pulmonary artery, and trace

experiment. Hold the heart in the left hand, with the ventral surface in the palm, and the tips of the fingers against the right ventricle. Hold the heart under a faucet, or pour from a pitcher, and let the water run first gently, then strongly, through the right auricle into the right ventricle. Watch the **tricuspid valves** as they float up and separate the auricle from the ventricle. Empty the heart and fill it again, and as soon as the valves rise, press with the fingers on the outside of the ventricle. What effect has this pressure? Let the nozzle of the faucet project down between the valves, and again turn on the water. Where does the water escape?

4. Empty the heart and examine the valves. They will be found lying close against the walls of the ventricle. Note the white tendinous cords attached to the valves.

5. Push the finger past these valves to the very bottom of the ventricle; from the outside cut through the wall of the ventricle at this point, and cautiously cut upward in both directions along the border of the ventricle. Raise the outer wall of the ventricle, and study the valves more thoroughly; with the scalpel handle raise them from the walls of the ventricle. How many flaps are there? How are they arranged? The conical elevations of the muscle to which the tendinous cords are attached are the **papillary muscles.** How are the valves held in place? How are they acted on, and how do they act?

6. Find the connection between the right ventricle and the pulmonary artery; pass a probe up into the pulmonary artery. Cut away enough of the wall of the ventricle to show the beginning of the artery. Cut off the pulmonary artery just before it forks to the two lungs; slip over the faucet the end of the artery connected with the heart, and turn on a little water. Watch closely the base of the artery; turn on more water, and look from below at the base of the artery, to see the filling of the pocketlike **semilunar valves.** Note their number, shape, and arrangement. What is the effect of the stream of water upon them, and what is their effect upon the stream of water?

7. Examine the left auricle, and find where the pulmonary veins enter it. Cut away the lobe of the left auricle; examine its inner surface, and find the openings of the pulmonary veins. Hold under a faucet, and prove the action of the **mitral valve**, between the left auricle and the left ventricle. Insert the nozzle of the faucet between the valves, and again turn on the water. Where does it escape? Cut off the aorta half an inch from its base, and repeat the last experiment with the water, meanwhile closely watching the semilunar valves of the aorta.

8. Above the pockets of the semilunar valves look for the openings of the **cardiac** (coronary) **arteries**, which supply the walls of the heart. Probe them. How many are there?

9. Pass the handle of the scalpel between the semilunar valves of the aorta into the left ventricle; it passes back of one flap of the mitral valve.

10. Cut open the left ventricle. Note the strong muscular columns, the strong papillary muscles; the mitral valve, though ending in two main flaps below, is continuous at the top. The valves between the auricles and ventricles are sometimes called the **auriculo-ventricular** valves. This may be shortened to "**aur-vent**" valves, and will be easily remembered, as the parts of the word indicate the two cavities between which the valves lie. Compare the walls of the right with those of the left ventricle. Why this difference? Note the partition between the ventricles. Is there any direct communication between the right and left halves of the heart?

11. Slit open the aorta between two of the semilunar valves, and study the valves more closely. In the middle of the free border of each valve note the little thickened point, the **corpus arantii**. When the valves close, these three little points fill up a small, three-cornered opening that would otherwise be left between the valves. These valves are sometimes called the **ventriculo-arterial**, or, for short, the "**vent-art**" valves, as they lie between the ventricles and the arteries. Again examine the cardiac arteries.

12. In another heart, carefully cut around the base of the pulmonary artery, tie its outer end tightly over the end of a glass tube or spool, and show the action of the semilunar valves, by blowing suddenly and forcibly into the tube. To keep the glass tube from slipping out, slip an inch of thick rubber tubing on the end of the glass tube, so that the rubber tube is even with the end of the glass tube. The valves work better when moist and flexible; therefore keep the preparation standing in a jar of water until it is to be used. Slit open the artery, and study the valves.

13. Longitudinal and cross sections of a frozen heart are instructive.

The Distribution of the Arteries and Veins in the Cat or Rabbit (injected). — Directions for injecting are given in suggestions "To the Teacher." 1. The main artery, the **aorta**, is a thick-walled tube, springing forward from the center of the base of the heart. It soon arches over to the left, and runs along the middle of the dorsal wall of the chest cavity.

2. At the bend, or **arch**, the aorta gives off two branches (three in man). The first of these soon subdivides, giving off a branch to the right fore limb, the **right subclavian** artery; two branches running along the side of the windpipe are the **right** and **left carotid** arteries. The second branch of the aorta runs to the left fore limb, and is the **left subclavian** artery.

3. During its course through the thorax the aorta is called the **thoracic aorta**. Trace it to the point where it runs through the diaphragm. It then becomes the **abdominal aorta**. Turn the stomach and intestine over to the right, and observe the abdominal aorta running along the dorsal wall of the abdomen. Just posterior to the diaphragm, a branch is given off which subdivides, and gives branches to the stomach, liver, and spleen. Farther back a large branch is given off to the small intestine. Follow it as it branches into the mesentery. This is the **anterior mesenteric artery**. Find the branches of the aorta that lead to the kidneys, the **renal arteries**. Some other branches may

be seen, and finally the aorta divides into two large branches, the **common iliacs**, supplying the two hind limbs.

4. Turn the stomach and intestines to the left, and observe the two veins running forward from the two hind limbs. These are the two **external iliac veins.** By their union they form the **postcaval vein.**

5. Observe the veins from the kidneys, the **renal veins.**

6. Trace the postcaval vein to the liver. Observe the vein that gathers the blood from the intestine, the **mesenteric vein.** This vein is joined by a vein from the stomach, the **gastric vein**, one from the spleen, the **splenic**, and one from the pancreas, the **pancreatic**; together these form the **portal vein,** which empties into the liver. Unlike other veins, the portal vein subdivides, distributing the blood into the liver. The blood thus distributed through the liver is re-collected, and by the **hepatic veins** joins the postcaval vein, close to the diaphragm, and almost wholly concealed by the liver.

7. The postcaval vein passes by the liver, through the diaphragm, and on to the right auricle.

8. On removing the skin of the neck, there should be found on each side the large **jugular vein.** Each of these is formed by the union of the internal and external jugular veins.

9. Just before each jugular vein enters the chest cavity it is joined by a vein coming from the corresponding fore limb, the **right** and **left subclavian veins.** The union on each side forms the **innominate vein.** The two innominate veins, uniting, make the **precaval vein**, which enters the right auricle. In the rabbit there are two precaval veins.

THE VALVES IN THE VEINS.

Dissect back the skin from the throat of the rabbit, cat, or dog, till the jugular veins are well exposed. Let the head of the animal hang over the edge of the table; note that as the blood presses back toward the head it causes marked bulging at certain points; with the handle of the forceps slightly stroke

the vein toward the head, watching the bulgings. Dissect out the jugular vein from the head to the shoulder; insert the nozzle of a syringe, first into one end and then into the other, and show the effect of forcing currents in each direction. Cut the vein open along one side, pin inside out to a piece of a shingle, and examine the thin, pocketlike valves. Test the elasticity of the vein. Note the smoothness of its inner coat. Remove a piece of an artery and experiment in the same way with it.

THE KIDNEY.

The structure of the rabbit's kidney may be made out by the following directions, but the sheep's kidney, being larger and essentially similar, may be conveniently used. If the sheep kidney be used, its dissection may be made later.

1. Observe the depression in the inner border of the kidney, the **hilum**.

2. From the hilum trace a slender white tube, the **ureter**, back to the bladder. Find also the renal artery and vein, branching as they enter the kidney through the hilum.

3. With a sharp knife split the kidney like a bean, beginning at the outer border, stopping the cut when a white membrane is reached near the hilum. With forceps pry about to explore the cavity between this white membrane and the body of the kidney. Note the branches of this cavity into the kidney. Note also the extension of the white membrane into these cavities. Make out that the blood tubes extend through these white branches to the outer parts of the kidney. Count these branches.

4. In the center of the white membrane find the opening of the ureter, by which the urine is conveyed to the bladder. Pass a probe through this opening into the ureter.

5. Note the difference in color of the outer and inner parts of the kidney. At the line of change of color find where the blood tubes first branch into the real kidney substance. Examine carefully the cut surface of the kidney to see its markings.

6. Make a drawing of one half of the kidney as seen from the inside, showing all the above-named points.

7. Cut across the middle of the kidney at right angles to its length, and make a drawing of this cross section. The projection of the kidney substance into the cavity opposite the ureter is the **urinary pyramid,** and from its apex, from many fine holes, issues the urine which the kidney has secreted from the blood.

DISSECTION OF THE HEAD OF A RABBIT.

1. Remove the skin from the head. Observe the cartilages of the ears and cut them off close to the head.

2. Below and back of the ear is an irregular pinkish mass, the **parotid salivary gland.** The duct which conveys the saliva runs forward over the cheek and opens on the inside of it. The duct is usually hard to see, as it is thin-walled, slender, and of about the same color as the sheaths of the muscles on which it lies. It may easily be mistaken for a nerve, several of which should now be in sight. This duct is much more readily traced in a dog. With sharp, fine-pointed scissors cut into the edge of the duct, insert a black bristle, and push toward the front.

3. Just back of the angle of the lower jaw find a roundish body, the **submaxillary** salivary gland. Its duct runs forward inside the lower jaw and opens under the front part of the tongue. It is rather difficult to trace in the rabbit, but is much easier in the dog.

4. The **infraorbital gland** is just below the front of the eye and its duct opens near that of the parotid gland.

5. The **sublingual gland** is a small, slender gland close to the inside of the lower jaw in front of the base of the tongue, and its duct opens near that of the submaxillary.

6. Observe the muscle that covers the outside of the back part of each lower jaw. This is the **masseter muscle.** Place the fingers on the angles of your own jaw and note the action of the masseter muscles in shutting the teeth firmly together. In the rabbit note the attachment of the masseter muscle to the

under edge of the cheek bone. Trim the muscle entirely away, noting carefully all its connections.

7. The **temporal muscle** is attached to the thin wing, or process, of the jaw in front of the hinge, and passes up inside of the arch of the cheek bone and spreads over the temple. The shortening of the masseter and temporal muscles is what shuts the jaws together. Remove this muscle, observing closely all its relations. Place the tips of the fingers on your temples and shut the teeth firmly together; the hardening of the temporal muscle is felt.

8. After removing the submaxillary glands a muscle may be found on each side attached to the inside of each half-jaw near their union in front. These are the **digastric muscles**; prove that when they shorten they depress the lower jaw. Trace these muscles to their connections at both ends. Review these points till you see clearly how the jaw is opened and shut.

9. Cut away the soft membrane on the side of the mouth. Note its inner surface. Split the two halves of the lower jaw apart in front by a strong knife used from below. Entirely remove one half-jaw, noting a muscle attached to the inner surface of the back part of the jaw. Look at its inner side for the hole where the nerve and blood tubes entered it. Do you find a hole on the outside of the jaw?

10. Examine the tongue; how much of the space does it fill when the mouth is closed? What is its shape? The projections on its surface are called the **papillæ**.

11. Examine the roof of the mouth. Press against it to find whether or not there is bone back of the soft membrane. This is the **hard palate**; note any markings or peculiarities of appearance. Follow it back till you reach the **soft palate**, which has no bony wall just beyond it. Follow the soft palate back, cutting away as much as is necessary of the lateral wall, making the opening cut along the level where the teeth meet.

12. Back of the soft palate is the cavity called the **pharynx**; it is a continuation of the mouth. Trace forward the passage

from the pharynx, over the soft palate, into the **nasal passages** above the hard palate. Trace the pharynx downward and backward to two passageways; the farther one is the **gullet**, or food tube, leading to the stomach; the nearer opening is the **glottis**, or opening to the windpipe, leading to the lungs. Between the glottis and the base of the tongue find the **epiglottis**, a spoon-shaped cartilage, which most of the time stands up close to the base of the tongue; but when food passes it turns down and back and covers the glottis, so that food does not enter the air tube. Study these parts and their movements till their action is clear to you.

13. Split the soft palate and turn the parts aside to find on the sides of the pharynx the small openings of the Eustachian tubes, that lead outward on each side to the cavity of the middle ear.

CHAPTER XIV.

MAMMALIA (*Concluded*).

The Brain and Spinal Cord of the Rabbit. — It will be found helpful to have at hand a well-mounted skeleton of a cat or rabbit. Note carefully (*a*) the cavity of the cranium, (*b*) the cavity in the spinal column, and (*c*) the sides of each neural ring where the bone is to be cut by the bone forceps, as indicated in Figure 1.

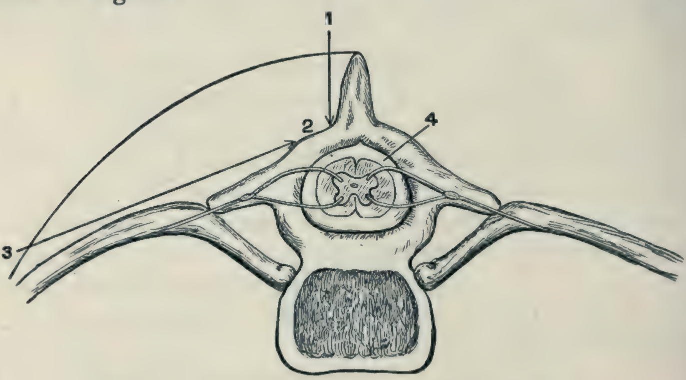

FIG. 1. DIAGRAM FOR DISSECTING SPINAL CORD.

1. Cut along 1 —— 2 with cartilage knife. 2. Cut along 3 —— 2 with cartilage knife. 3. Cut along 4 with bone forceps.

It is best to remove the skin completely before beginning the work, as the fur is likely to be troublesome.

Cut away the muscles from the back of the neck and along the sides of the backbone. This can be done rapidly by making long, deep cuts with the cartilage knife along the sides of the backbone, in the planes indicated in the accompanying figure.

Between the skull and the first vertebra is a space covered by a thin membrane, through which the **spinal cord** may be seen. Carefully cut through this membrane, and insert the point of one blade of a pair of bone forceps at one side of the spinal cord. Cut through this side of the arch of the vertebra; repeat this on the other side, and so on, through the whole length of the spinal column, removing the dorsal parts of the vertebræ, held together in one strip by the connective tissue. The bony cavity in which the spinal cord lies is the **neural cavity.**

The work may be more easily done if the rabbit is supported on the edge of a short piece of "two by four" scantling nailed to a baseboard eight inches wide and a foot and a half long.

Now look for the **spinal nerves,** which leave the spinal cord in pairs, right and left, between the successive vertebræ. It will probably be necessary to cut away considerably more bone to expose the nerves. The whole of this work requires the utmost care and patience, and involves a good deal of hard labor.

Note carefully the variations in the diameter of the spinal cord in its course. The anterior swelling is called the **cervical enlargement**, and the posterior is the **lumbar enlargement.**

When the spinal nerves have all been laid bare, count and compare them in reference to: (1) size; (2) intervals between successive pairs; (3) angles at which they leave the spinal cord.

Carefully cut away the bone around some of the nerves in the region of the shoulder, and find the two roots by which each nerve is connected with the cord, one nearer the back, the **dorsal root**, and one nearer the ventral surface of the body, the **ventral root.** Trace these two roots, and note that they unite and form a spinal nerve.

On the dorsal root, just before it joins the ventral, is a small swelling, the **ganglion** of the dorsal root.

In the region of the shoulder carefully trace several of the nerves as they unite to form the **brachial plexus,** from which nerves supply the fore limb.

In the region of the hips trace several of the spinal nerves

to their union in the large **sciatic nerve**, which runs down the thigh.

Turn now to the head, and cut into the bone between the eyes. Cautiously working backward, the whole of the brain may be unroofed. Great care must be exercised, for here we have one of the softest of the tissues of the body lying very closely beneath one of the hardest. It is possible to do this work with a strong knife, but the bone forceps save a vast amount of extra work. The bone must be broken away bit by bit.

Compare the color of the brain with that of the spinal cord.

The tough membrane covering the brain is the **dura mater**.

The fore part of the brain is the **cerebrum**. Note the groove separating it into the right and left **hemispheres**. Observe the ridges, or **convolutions**, of its surface. The prolongations of the brain between the eyes are the **olfactory lobes**.

Back of the cerebrum is the **cerebellum**. Look at the human skull to see whether there is a bony partition corresponding to that which separates the cerebrum from the cerebellum in the rabbit.

The widening part of the spinal cord within the skull is the **spinal bulb**.

Make a drawing of the brain and spinal cord, showing as many as possible of the points above noted. If desired, the brain and cord, with a short part of each nerve, may be removed from the body and laid on a cushion of cotton in weak alcohol.

Directions for preparing the Brain of a Cat or Rabbit. — Directions have been given above for uncovering the brain. To remove the brain, it will be necessary to cut through the tough **dura mater** that covers it.

Removing this, there will be found an inner covering, the **pia mater**, a membrane richly supplied with blood tubes, from which the brain gets its nourishment. After the dura mater has been removed, the anterior end of the brain may be gently lifted

with the handle of the scalpel and the under surface studied, following the directions in finding the cranial nerves.

The brain may be studied while it is fresh, but it is more easily handled after it has been hardened. Lay the brain in weak alcohol, about twenty-five per cent. It should rest on a layer of cotton, otherwise it may be very much flattened by its own weight, and get a good deal out of shape. Later transfer it to fifty per cent alcohol, and then to seventy-five per cent; or use a solution of alcohol and formalin as follows: ninety-five per cent alcohol, sixty parts; two per cent formalin, forty parts. The liquid need not be changed if used in sufficient volume. When it is well hardened, it may be sliced with a sharp scalpel as directed.

The Brain of the Rabbit (*Alcoholic Specimen*). — The brain of a cat or dog is better, being larger. Take a brain well hardened, and review the parts as named above. It is very desirable to have a specimen in which the arteries have been injected.

1. Press down the cerebellum, to see the deep groove between it and the cerebrum. The thin membrane covering the brain and dipping into the grooves is the **pia mater**.

2. Press down the spinal bulb and tear away the pia mater where it passes from the cerebellum to the spinal bulb. Note, between the bulb and the cerebellum, a space covered by a thin membrane. Cut into this membrane; the cavity is the **fourth ventricle** of the brain. Observe the two ridges bounding the sides of the fourth ventricle. At the point of their divergence, observe the opening of the **central canal** of the spinal cord.

3. Gently separate the cerebral hemispheres, and note the transverse band of white fibers connecting them.

4. Examine the under surface of the brain, and find the roots of the cranial nerves.

The Cranial Nerves. — 1. The **olfactory lobes** (probably cut or broken off) extend forward from the fore part of the cerebral hemispheres.

2. Note that the **optic nerves** join each other before reaching

the brain. Only the first and second pairs of cranial nerves directly enter the cerebrum.

3. Back of the optic nerves, near the middle line, is the **third pair** of nerves.

4. The **fourth pair** extend up on each side into the groove between the cerebrum and the cerebellum.

5. Back of these is the larger **fifth pair**. This pair supplies part of the face, and sends branches to the teeth. It is the nerve affected in neuralgia of the face.

6. Back of and inside of the fifth pair is the **sixth pair**.

7. The nerves of the **seventh pair** are larger, and are farther back and outward. These are the **facial nerves**, and control the muscles of the face and the facial expression.

8. Close to the seventh are the **eighth**, or **auditory nerves**.

9. The **ninth**, **tenth**, and **eleventh** arise close together, farther back and well up on the sides of the **spinal bulb**.

10. The ninth supplies the back of tongue and the pharynx, and is called the **glosso-pharyngeal nerve**.

11. The tenth pair pass down out of the brain cavity, give off branches to the pharynx and larynx, and are distributed to the heart, lungs, and stomach. These are the **vagus nerves**.

12. The last pair of cranial nerves, the **twelfth**, arise near the middle line of the spinal bulb. This pair supply the muscles of the tongue, and are called the **hypoglossal nerves**.

Draw the brain as seen from below, showing all these nerves.

Separate the cerebral hemispheres, and with a sharp knife split the brain lengthwise in the middle line. Make a drawing of the inner face of one half. Note the branched appearance, the **arbor vitæ**, of the cerebellum. Trace the cavities of the brain.

THE LEGS OF THE RABBIT.

Most of the following structures may be made out from a shin bone of a sheep, readily obtained from the butcher.

1. After removing the skin from the legs, observe the **muscles**,

covered by a thin, glistening membrane, the **muscle sheath.** Study the shapes of the muscles.

2. In the hind limb of the rabbit observe the heel cord, or Achilles tendon, passing upward from the heel along the back of the leg. The tendon is the termination of the calf muscle, which lies on the back of the shin bone. Trace this muscle toward the body, and note that it passes between two large, flat muscles, one on the inner, the other on the outer, back part of the thigh. Separate these two flat muscles, using mainly the handle of the scalpel. Remove any fat that may be in the way. Deeply embedded between these muscles is a white cord, the **sciatic nerve.** Trace this nerve toward the body, cutting away any muscles or soft tissue covering it. How far can you trace it? Now follow the nerve outward. Is it of the same size throughout? What are its relations to the muscles?

3. Study carefully the calf muscle, its shape, color, covering, ends, etc. The end by which its tendon is attached to the heel bone is the **insertion**; the other, less movable end is the **origin.** From what bone does it arise, and by how many tendons? Cut across the muscle at its thickest part, the belly of the muscle, and study its structure. Note that the tendons at the ends of the muscle are continuous with the muscle sheath and with the partitions running through the muscle. Pull the tendon toward the body; this straightens, or extends, the foot; the calf muscle is therefore called an **extensor** muscle. With the handle of the scalpel loosen the muscle on the front of the shin bone; prove that its action is to bend, or flex, the foot. It is a **flexor.** Find its origin and insertion.

4. By further dissection find how the different movements of the toes are effected.

5. Cut into the knee joint. Observe the liquid, the **synovia,** which oils the joint. Rub a drop of it between the thumb and finger.

6. Observe the glistening bands which hold the ends of the bones together. These are the **ligaments.** Carefully study their arrangement and uses.

7. Note the thin layer of **cartilage** over the ends of the bones. Feel of it. Cut it. What are its properties, and what its uses?

8. With the forceps strip off a little of the muscle sheath from one of the muscles and note the color of the latter. Cut one of the muscles across in its middle and examine the cross section. Each fiber has its own thin sheath, and the small bundles of fibers have separate sheaths, which make the white markings seen in chipped dried beef.

9. Tear off a few fine fibers of the muscle, mount on a slide in water or glycerine, cover with a cover slip, and examine first with a low and then with a high power. The fine cross-markings of the fibers give to this kind of muscle the name of **striped, or striated, muscle.**

10. The covering of the bones is the **periosteum.** Thoroughly clean one of the long bones and make a drawing of it. Saw it in two lengthwise and make a drawing of the surface thus exposed. Put a bone into weak acid, and after a day or two compare it with another that has been burned.

THE MUSCLES OF THE EYEBALL.

With bone forceps, or a strong knife, cut away the bone at the outer angle of the eye socket of the rabbit (almost any mammal will serve for this, but the bone is so thick in the calf or sheep that it will be difficult work without the aid of a good pair of bone forceps).

1. With scissors trim away the white membrane around the front of the white of the eye; this was continuous with the lining of the eyelid, and is the **conjunctiva.**

2. Find a muscle running along the roof of the eye socket, which passes over a loop of tendon, near the edge of the orbit, and turns outward to its attachment to the top of the eyeball. This is the **superior oblique muscle.**

3. Beneath the eye find a muscle, having its origin in the inner front part of the socket, and passing outward to be

inserted in the lower surface of the eyeball; this is the **inferior oblique muscle.**

4. Four straight muscles, the **superior rectus, inferior rectus, internal rectus,** and **external rectus,** are attached to the top, bottom, and sides of the eyeball; find the origin of these, with that of the superior oblique, at the bottom of the eye socket.

5. Dissect away the fat and other tissue around these muscles, and find a cone-shaped muscle attached to the back of the eye. Within this find the cylindrical **optic nerve.**

External Parts of the Eye. — The eye of the rabbit may be used, but that of the ox is better.

1. Observe the clear front part of the eye, the **cornea.** Note its shape. Its wider end was at the inner angle of the eyelids.

2. Around the cornea find a whitish membrane, the **conjunctiva,** which, a short distance back from the cornea, separates from the eyeball to turn forward and line the eyelid.

3. The several muscles of the eyeball, a mass of fat which forms a cushion for the eye, and other tissue, should be trimmed away, leaving the **optic nerve.**

4. Place the eye in its natural position, and make drawings of it, as seen from the front and from one side, naming the parts.

Dissection of the Eye. — Beef eyes are of good size for dissection. Each member of the class should have an eye to dissect. To supply a large class it is best to send to a slaughtering house in the nearest large city. If the eye muscles and other external parts have already been studied, it will not be necessary to remove the muscles and fat around the eye; in fact, they may well be left untouched, as they serve as a cushion to support the eye during dissection. The eye may be conveniently dissected on a small piece of board or shingle; and if it is desirable to turn the eye, it is better to do so by turning the support, as the eye usually sticks to the support and the dissection may be injured by trying to move it.

Caution. — After the eye is opened be careful **not** to **compress**

it. If the eye be held in the hand while trying to cut its tough outer coat, the jellylike contents are easily squeezed out, ruining the dissection. **Let the eye rest on the board all the time,** and after first cutting into the cornea it is not necessary nor advisable to touch it with the fingers. When studying the lens, be very careful to tip it up gently and compare its front and back surfaces before removing it from the eye..

1. Lay the eye on the board, with the cornea uppermost. Hold the eye firmly with the thumb and fingers of one hand; with the thumb and forefinger of the other hand hold the blade of the scalpel half an inch from its tip; with a steady motion push the blade horizontally through the cornea, near its edge.

2. The liquid in the cavity back of the cornea is the **aqueous humor.**

3. Slightly enlarge the cut horizontally; then with the forceps take hold of the upper edge of the cut, and with the scissors cut around the margin of the cornea and remove it.

4. The dark membrane now exposed is the **iris.** Pinch the eye slightly at the sides to make the iris show more distinctly. The hole in its center is the **pupil.** With the forceps raise the edge of the iris around the margin of the pupil to see that it is here unattached to the structures underneath. Observe the color and markings of the iris.

5. From one end of the pupil cut outward to the outer margin of the iris; then cut around its outer margin and remove it. Observe the color and markings of the posterior surface.

6. The body now laid bare is the **crystalline lens.** Touch it.

7. Lay a piece of newspaper *close* to the eye, on which to receive the lens, which sometimes pops out suddenly. With a very sharp blade make a quick, light gash across the surface of the lens to cut through the thin coat which envelops it, the **lens capsule.** Usually the lens may be made to come out by applying gentle pressure to the sides of the eye with the thumb and finger. If not, enlarge the opening thus made, and carefully pry up the

lens with the handle of the forceps, noting closely, in so doing, the difference between the front and back surfaces. Lay the tens on the piece of newspaper, and look through it at the letters. Make a drawing of the lens as seen from the front, and as seen from one side, naming the front and back surfaces.

8. (Caution. — In removing the strip of eye coating, as directed below, be extremely careful not to drag the clear, jellylike vitreous humor. The strip must not be unwound, as in peeling an apple, but must be **left in place**. The parts must be lifted gently by the forceps, and the clear, jellylike mass must be cut through horizontally, with the scissors.) With the scissors now cut outward about one half of an inch from the edge of the hole made in front of the eye, merely cutting through the outer wall of the eye. Beginning at the lower end of this last cut, with scissors cut through the coats of the eye, horizontally, all around the eye. With forceps take hold of the upper edge of the coats of the eye, and lift very gently and steadily while cutting horizontally through the jellylike contents of the eye, in the plane of the circular cut just made. Lay the part thus cut off wrong side up on the board. On the inside of the strip removed there may be found radiating black ridges, the **ciliary processes.**

9. Carefully pick away with the forceps, and snip away with the scissors, everything on the surface of the clear mass beneath.

10. The substance filling the remainder of the eye cavity is the **vitreous humor**.

11. Through the vitreous humor the entrance of the optic nerve may be seen with the blood tubes radiating from it. If necessary, carry the dissecting board to a window to let the light enter from above.

12. The tough outer coat of the eye is the **sclerotic coat.**

13. Inside the sclerotic is the dark **choroid coat**.

14. The inner, nearly transparent, pinkish or whitish coat is **the retina.** At this stage of the dissection it has probably become slightly wrinkled, and the white ridges may be seen radiating from the entrance of the optic nerve.

Drag out the vitreous humor and note the soft whitish or pinkish retina; observe that it is a continuation of the optic nerve. Tear away the retina, noting its consistency. Note the color and luster of the inner surface of the choroid coat. The dark layer on the inside of the choroid coat is the pigment layer (outer part) of the retina, which adheres to the choroid, and is torn loose from the rest of the retina.

The reflection of light from this surface of the choroid coat causes the color seen in the eyes of some animals. Turn the remaining coats inside out, and tear the choroid coat from the sclerotic. Observe the blood tubes passing from one to the other.

DISSECTION OF THE LARYNX.

The Larynx of the Calf. (As the larynx of the rabbit is so small, it will be better to examine a larger one.) — 1. The front of the larynx is readily distinguished by the projection of cartilage known as the **Adam's apple.**

2. Along the back of the larynx runs a thick, muscular tube, the **gullet**, with a whitish lining, the mucous membrane.

3. Trim away the muscles and other tissues from the front and sides of the larynx. The large cartilage forming the greater part of the front of the larynx is the **thyroid cartilage**.

4. Observe the band of muscles attached to either side of the thyroid cartilage and passing horizontally back around the gullet or esophagus.

Cut away this muscle as completely as possible, and entirely remove the gullet. Note that the whitish or yellowish **mucous membrane** which lines the gullet is continuous with the lining of the larynx. Study now more fully the shape of the thyroid cartilage.

5. Back of the upper part of the thyroid cartilage, covering the upper end of the larynx, is the arched **epiglottis**. Feel of it to learn its consistency. Press it upward and forward, then downward and backward; observe that it now covers the entrance to the larynx; note the position it takes when released.

6. Just back of the upper angle of the thyroid cartilage find a muscle connected with the base of the epiglottis; pull this muscle to determine what effect its shortening produces on the epiglottis.

7. Under the thyroid cartilage in front observe a narrow ring of cartilage not much wider than one of the rings of the trachea. Move this up and down to prove that it is distinct from the thyroid. This is the **cricoid cartilage.**

8. Observe the sheet of muscle passing from the cricoid to the thyroid. Again move the cricoid toward and from the thyroid. What does this muscle do? Cut away this muscle from one side, and see that the cricoid cartilage widens as it passes backward. How are the cricoid and thyroid hinged together?

9. Projecting upward and backward from the top of the larynx are two curved yellowish cartilages, the **arytenoid cartilages.** Move them about to see that they are movable, and that they rest on the upper edge of the back part of the cricoid cartilage.

10. Move the arytenoid cartilages backward and forward, meanwhile watching the inside of the larynx from its lower opening. The projecting ridges, which meet just back of the Adam's apple, are the **vocal cords.** What effect is produced on the vocal cords by the movements of the arytenoid cartilages?

11. Observe the connection of the thyroid cartilage with the cricoid by means of a downward projection of the former. Cut away all of this half of the thyroid cartilage. Notice the slender **hyoid bone** loosely connected with the upper horn of the thyroid.

12. Examine now the muscles which move the arytenoid cartilages.

a. On each side of the posterior surface of the cricoid is a muscle passing upward to be attached to the corresponding arytenoid; this is the **posterior crico-arytenoid muscle.** Dissect it loose from the cricoid at its origin below. By pulling, determine its action on the arytenoid, and through the arytenoid on the vocal cord.

b. Arising from the upper edge of the side of the cricoid cartilage, and passing upward and backward to the arytenoid, is

the **lateral crico-arytenoid muscle**; cut it away at its origin close to the cricoid, and demonstrate its action on the arytenoid cartilage and vocal cord.

c. A broad muscle arising along the whole length of the angle of the thyroid, whose fibers converge to the arytenoid cartilage. This is the **thyro-arytenoid muscle**; cut it across near its origin, dissect it loose, and by pulling it toward its origin prove its action.

d. On the posterior surface of the arytenoids is the small **arytenoid muscle.**

13. Cut between the arytenoid cartilages and remove one of them. Examine the joint between the arytenoid and cricoid. Note the synovia lubricating the joint.

Trim away the muscle from the arytenoid cartilage and study its shape more fully. Fit it again to its place, and recall the motions given by each muscle.

14. Now examine the arytenoid cartilage and the vocal cord of the opposite side; move the arytenoid back and forth, watching the vocal cord.

15. Remove the epiglottis, and cut into it to see its structure.

16. Dissect away the parts of the other side from the inside, reviewing the above points.

THE SKELETON OF THE RABBIT.

Carefully clean the skeleton after dissecting away the muscles. In preparing the skeleton in this way the student will learn many facts as to the relations of the bones to the other tissues, that he would not learn if he began with a well-mounted museum skeleton.

In removing the muscles, observe that the muscles of the limbs lie parallel to the bones; that the bones are largest at the ends, while the muscles are thickest near the middle, thus making the two fit each other better. Note that in the limbs the muscles narrow at one end, or both, into a **tendon**, which, usually at one end, passes over a joint to be attached to a bone

in the next part of the limb. Examine the **ligaments** that hold the adjoining ends of the bones together. Examine the **cartilage** on the end of the bones. Between the ends of the bones of the limbs, note a small quantity of slippery liquid, the **synovia**. In cleaning the bones, notice the nerves and blood tubes passing in and out of the holes along the sides of the bones.

Weigh a rabbit, freshly killed, but from which the blood has not been removed. Thoroughly clean the skeleton, and when it is dry, weigh it. What part of the whole weight of a rabbit is the skeleton?

1. The skeleton consists of two parts, the **axial part**, made up of the skull and spinal column, and the **appendicular part**, consisting of the limbs and the bones supporting them.

2. In the skull, the joints are called **sutures**. The bones surrounding the brain constitute the **cranial** part; those parts in front make up the **facial** part. Note that the face is large, compared to the cranium. How do these two parts compare in the rabbit, dog, horse, frog, ape, and man? Why so much difference? Note the cavities and apertures in the skull: the brain cavity; the opening (foramen magnum) through which the spinal cord passes to join the brain; the cavity, or **orbit**, of the eye, with its holes for the optic nerve; the **nasal apertures at** the front of the snout; the **auditory apertures**, or ear holes. On each side of the foramen is a smooth, rounded elevation; these are the **occipital condyles**. See how they fit the first vertebra; what kind of a joint do they make? Study again the way the lower jaw joins the skull, and consider the motions that this joint permits. Compare it with the corresponding joints in the skulls of a cat, cow, and man.

3. Make a more careful study of the teeth than before, as they are now fully exposed. The front teeth are the **incisors**; what is their shape? How many above? How many below? Are they all alike? How are they arranged? Are they all marked alike? How do the upper and lower incisors meet, —

squarely, edge to edge, or does one pair naturally rest back of the others? If so, which are in front in the resting position? Can the lower jaw be moved forward and back? Do the lower incisors always come up in the same position in relation to the upper incisors? Note the angle at which the incisors are set. Now examine the grinding teeth, or **molars**. How many are there in each half-jaw? What is their shape? Are there ridges on their grinding surfaces? If so, in what direction do they run? How is this related to the chief chewing motion? Are all the molars set at the same angle? Why any difference? At this point, if possible, look again at a live rabbit and watch the process of eating. How are the jaws moved, and how do the motions stand related to all these facts about the teeth?

4. Take a well-cleaned lower jaw of a rabbit. Embed it in sealing wax on a small block of wood, with the inner face of the jaw uppermost. With a grindstone, grind away half of the incisor and the surrounding jawbone. Is there a distinct root? Is the tooth equally hard throughout? The front part is **enamel.** The bulk of the tooth consists of **dentine**, or ivory. Grind away half of the molars and the bone in which they are set. Do any of these teeth continue growing after the rabbit has reached maturity? Is it a serious matter for a rabbit to lose one of its front teeth? Why?

5. Each separate piece of the backbone is a **vertebra.** The vertebræ of the neck are called **cervical vertebræ.** The vertebræ that bear ribs are **thoracic.** Following the thoracic vertebræ are the **lumbar vertebræ.** After these, are several grown together and supporting the bones of the pelvis; they constitute the **sacrum.** Last, the vertebræ of the tail, the **caudal vertebræ.** How many are there of each of these kinds? How many in all? Review the whole spinal column, comparing the different parts.

Take a vertebra from the middle of the thorax and examine it carefully. Its main part is the **body** or **centrum.** On the dorsal side is an arch, the **neural arch,** through which the spinal cord passed. Above the arch is a projection, the **neural spine,** the

row of neural spines forming the ridge of the backbone. Extending outward on each side are the two **transverse processes.** Near the end, on the dorsal surface, are the two smooth **facets,** where the vertebra joined the vertebræ before and behind it; these are the **articulating processes.** Do all the vertebræ have the same number of the processes? Where the same number is present are they alike? What range of motion is allowed between two vertebræ? Is this equal in different parts of the spinal column?

6. Study carefully the first and second vertebræ. The first is the **atlas.** Has it a body? Note how the two hollowed facets on each side of the hole fit the two occipital condyles of the base of the skull. How is the nodding motion of the head accomplished? The second vertebra is the **axis.** Projecting forward from it is a peg which extends into the opening in the atlas; this peg is the **odontoid process.** Observe that when the head turns from side to side it is by turning on this axis.

7. Examine one of the middle ribs. Find that it joins the backbone in two places, by its **head** on the side of the vertebra, and by a little projection called the **tubercle**, with the tip of a transverse process. What range of motion has a rib? Note that at the ventral end the rib is cartilaginous. What is the advantage of this fact? Compare the series of ribs. Examine the breastbone. Is it of one piece? Is there any cartilage in it? What are the uses of the ribs? Is there a **collar bone**?

8. In the fore limb look at the shoulder blade or **scapula.** How does it make up in strength for its thinness? Why should it be flat? Note the shallow cavity by which it articulates with the bone of the upper arm, the **humerus.** This is a **ball-and-socket joint.** Look closely for a slender collar bone, or **clavicle.** In the forearm the longer bone is the **ulna**; the other is the **radius.** Do they rotate on each other as in our forearms? Compare them also with the corresponding bones of a cat. Do they need the same freedom of motion as in a cat, squirrel, ape, or man? The bones of the wrist are the **carpal bones.** The

bones of the palm are the **metacarpal bones.** Beyond them are the finger bones, or **phalanges.** Find how many there are of each of these sets.

9. In the hind limb each half of the **pelvis** consists of the long **hip**, or **innominate bone.** Note the deep socket of the ball-and-socket joint. Fitting into this is the rounded head of the **femur,** or thigh bone. Compare this joint with that of the shoulder. Which has the greater range of motion? Which the greater strength? Study the kneejoint. Note the kneepan, or **patella,** in the tendon running over the kneejoint. The large bone of the leg, or shank, is the **tibia.** Beside it is the **fibula**; is it wholly free from the tibia? If it is found united with the tibia, where and to what extent? Corresponding to the carpus of the wrist, there is a series of short bones in the foot constituting the **tarsus.** Then comes a row of longer bones, the **metatarsal bones.** And after these are the toe bones or the **phalanges.** How many in each of these series and how arranged? Are the bones of the same number as in the fore limbs?

CHAPTER XV.

PROTOZOA.

AMŒBA.

Amœbæ are to be found in standing water, where they live in the slimy coating on the leaves and stems of submerged plants, or on the upper layer of mud or ooze at the bottom. Such water with mud and plants should be collected sometime beforehand and kept undisturbed in the laboratory.

1. Take a drop of water from the bottom or the surface of a leaf, mount on a slide, and cover with a cover slip. Examine with a high power of the microscope, using a one-fifth or a one-sixth inch objective.

2. **General Appearance.** — An amœba looks like a small drop of clear jelly, but after watching it a short time it may be seen to change its form. The body is composed of a substance called **protoplasm**.

3. **Structure.** — The following parts should be identified: —

a. A clear outer margin, the **ectosarc**.

b. A dotted or granular inner portion, the **endosarc**.

c. A denser, spherical body within the endosarc is the **nucleus**.

d. A clear space that from time to time contracts and disappears. This is the **contractile vesicle** or **vacuole**. Are its pulsations regular? Time them.

e. Other vacuoles that do not pulsate but are filled with granules of food materials. These are called **food vacuoles**.

4. **Movements.** — Watching the amœba closely shows that it not only changes its form, but also its position; it not only moves, but moves from place to place. It has not only motion, but locomotion. By closely watching an amœba it may be seen

that at one place there is a bulging out of the ectosarc, sometimes forming a long projection called a **pseudopod**. The granular endosarc then flows into this projection, and by repetition of this process the whole amœba moves forward. Is there any part that can be called the head? Does it move constantly in any one direction? Make sketches at intervals to show the changes in form.

5. **Feeding.** — It may be discovered that occasionally an amœba ingulfs a particle with which it comes in contact. This is its mode of eating, for it has no mouth. Does it show choice in what it thus takes in? Is there any refuse of digestion? If so, where and how does it leave the body?

6. **Feeling.** — Does the amœba ever appear to feel an object against which it presses? Does it avoid obstacles? What evidences as to its having a sense of touch?

7. **Reproduction.** — Can you find an amœba that is dividing into two parts? This is its simple mode of reproducing, and is called **division** or **fission**. If possible, find out how long it takes to complete the division. Make sketches to show the process of division.

PARAMECIUM, THE SLIPPER ANIMALCULE.

Paramecia are often found in water containing decaying animal or vegetable matter. If a white film forms on the surface of such water, look through the sides of the jar, and there may often be discovered tiny white particles moving actively about. Mount a drop of this water, with a little of the scum, and examine with a low power of the microscope, say a two-thirds or one-fourth inch objective. Small oval or elliptical bodies may be seen swimming around at a lively rate. These are paramecia. Find one that is fenced in by surrounding matter, or prepare another mount; a few threads of cotton often serve well as a "corral." With a higher power, one fifth or one sixth, examine a paramecium, whose movements are thus restricted. Note: —

1. **The shape**, oval or elliptical, often decidedly slipper-shaped. It further resembles a slipper in being somewhat flattened.

2. **Structure.** — The clearer, firmer, outer layer is the **ectosarc.** The more jellylike inner part is the **endosarc.** Covering the ectosarc is a thin, transparent layer, the **cuticle.** Extending from the ectosarc through the cuticle are many fine, hairlike projections, the **cilia.** Near the center is a large, ovoid body, the **macronucleus.** Beside it is the much smaller **micronucleus.** These nuclei are hard to see. Place a little dilute acetic acid on the slide close to the cover slip to bring out the two nuclei.

3. **Locomotion.** — The paramecium swims by means of the vibrations of the cilia. Does it swim with the same end always foremost? Does it change its shape? Watch it when trying to pass into a narrow opening. Are the cilia of the same size all over the body? Place a drop of iodine solution on the slide at the edge of the cover slip. The cilia, thus stained, show better.

4. **Feeding.** — Along one of the flattened surfaces find a groove, the **oral groove.** Note the cilia lining this groove. Observe that, near the center of the body, the oral groove becomes a tube dipping into the body. The tube is the **gullet,** and its beginning is the **mouth.** Sift finely powdered carmine or indigo into the water, and watch to see the particles swept into the gullet by the action of the cilia. The masses of particles that accumulate at the end of the gullet become separated from the gullet, and as distinct masses in the body are called **food vacuoles.** Do the food vacuoles remain in the same place? Or do they move about? Do they move in any regular order? Can you find a place where the residue is expelled from the body?

5. **Pulsating Vacuoles.** — About one third of the way from each end, look for a clear space, which contracts and disappears, and then reappears; these are the pulsating vacuoles, or contractile vesicles. How often do they pulsate? Which takes more time, contraction or dilation? Look closely for radiating canals after

the disappearance of a vacuole. Do the two vacuoles contract at the same time?

6. **Means of Defense.** — Observe in the ectosarc many small, oval sacs, with their ends toward the surface. These are the **thread cells**. They contain a thread, which can be shot out, serving as a means of defense.

7. **Reproduction.** — Do you find a paramecium that is becoming constricted in the middle like a dumb-bell or hourglass? Paramecium divides into two by narrowing in the middle, preceding which is a division of the nuclei. If such a specimen can be found, watch the process to completion, if possible. Draw and describe all the stages of division, or **fission**.

VORTICELLA, THE BELL ANIMALCULE.

Vorticellæ are often found on the stems and leaves of water plants, or on stems and leaves that have fallen into the water. Mount slender stems from water and examine with a low power. If you find a bell-shaped form attached by a slender, flexible stalk, and especially if the stalk is suddenly thrown into a coil, jerking the bell close to the stem to which it is attached, you may be sure you have vorticella or a near relative. Some of these forms occur in colonies, all growing from one main stalk. Some have the power of coiling the stalk, while in others the stalk is not contractile. Some of the colonies can be seen by the naked eye, appearing like tiny spots of mold. If such a colony is found, the part of the stem or leaf to which it is attached should be carefully cut out and mounted on a slide. With a higher power the details of form and structure may be studied.

1. **Form and Structure.** — The body is bell-shaped, with a long, slender, flexible stalk in place of a handle. The outer layer is a thin cuticle, next is the **ectosarc**, and the inner is the **endosarc**. The extension which nearly fills the mouth of the bell is the **disk**. The border of the bell is the **peristome**. On one side find a groove between the disk and the peristome. This

is the **oral groove**. Observe the cilia along the margins of the disk and the peristome. The extension of this groove into the body forms the **gullet**. Vorticella has a long, curved macronucleus and a small, spherical micronucleus, but these are not easily seen. Add a little dilute acetic acid.

2. **Movements.** — Observe carefully the stalk during and after the coiling. The stalk does not contain any of the endosarc, but only the ectosarc and cuticle. Note also the changes in the shape of the body and the rearrangement of the parts. In what order are the parts folded in during the act of closing, and in what order are they expanded when the vorticella extends again? Tap on the slide while watching to see these changes. Make sketches showing the fully expanded and the closed forms. Why does the vorticella thus draw itself close to its support?

3. **Feeding and Digestion.** — Watch the vibrations of the cilia. Can you see that food particles are swept into the oral groove and down to the blind end of the gullet? Add powdered carmine or indigo to the water. Can you see food balls at various points in the endosarc? Are they stationary, or do they move? If they move, do they go in any regular order? Look closely for the expulsion of residue into one side of the gullet, and so out by the return current. Does a vorticella move toward food? Could it do so? Does it need to do so? Does vorticella show choice in the particles that it takes as food?

4. **Excretion.** — Find the **pulsating vacuole**. Time its contractions.

5. **Senses.** — What senses does the vorticella appear to possess?

6. **Reproduction.** — Look for two vorticellæ on one stem. You may find one in the early stages of division. When one of these becomes separated, learn how it swims away. Study vorticellæ a long time to find out about the mode of development, making sketches of what you observe.

Topics for Reports. — Chalk. Barbadoes Earth. Malaria. Infusorial Earth.

CHAPTER XVI.

PORIFERA.

SPONGES.

Each pupil should have a small specimen of a commercial sponge, showing large holes at the top, but not with large holes running straight through.

The teacher will need several specimens of larger sponges; one of the simple calcareous sponges, in alcohol; a piece of commercial sponge in alcohol, showing the sponge flesh still in place; a siliceous sponge; and slides showing sponge spicules.

The pupil should make out the following points from his specimen of common sponge:—

1. Its elasticity; test first the specimen dry, and again after wetting it. Compare the elasticity of different kinds of sponges.

2. The fibrous structure; with forceps tear off a bit of the sponge and examine with a lens. Then examine under the microscope.

3. The sponge was attached by its basal surface to rock. Find where it has been trimmed away with shears; perhaps if this has not been thoroughly done, some bits of rock may be found clinging to the base.

4. Examine now the different channels by which the sponge is perforated.

a. Large, craterlike tubes, opening at the top of the sponge. Looking into these, it may be seen that they give off branches. If you can see right through the sponge by looking into these openings, you may know that too much of the base has been cut away, and your specimen is not a good one. With a razor or

sharp knife, cut the sponge in two down one of these large tubes, and examine from the inside.

b. Trace the branches of the large tubes by gently pushing into them a probe (a wire with a little knob on one end). These lead, usually, to holes seen on the outside.

c. Grooves on the surface of the sponge, some shallow, others already becoming inclosed by the union of the tufts of fibers outside of them; in this way is formed another set of tubes (*d*).

d. Tubes running parallel to the surface of the sponge, whose cut-off ends may be seen near the margins of the split sponge. Hold the half sponge up to the light to see the radiating fibers and the concentric series of holes indicating the mode of growth of the sponge.

e. Minute branches of the above tubes penetrating the sponge in all directions.

It must be borne in mind that the sponges we buy are only the skeletons of sponges. In the living sponge the skeleton is entirely embedded in soft living matter, and the skeleton cannot be seen on the exterior; in fact, its fibers are not very evident in a section of a fresh sponge. The outside of the sponges whose skeletons we buy, when alive resembles, in color and general appearance, the back of a kid glove, varying from dark reddish brown to almost black. The consistency of the living sponge is about the same as that of beef liver. If one of these live sponges be watched, a current of water is found to come out of the larger holes at the top, and currents pass in through the numerous smaller holes on the exterior.

If the sponge be handled, many of the smaller holes close and entirely disappear.

In order to understand a little more clearly the structure of the common sponge, and to see how the currents of water are maintained, an examination of a simple sponge will be useful. Our simplest sponges have no elastic skeleton composed of horny fibers like those of the commercial sponge, but have little needle-shaped and three-pronged spicules of limy matter.

One form common on the northern Atlantic coast is a simple or branched white tube, an inch or so in height, and sometimes as thick as a pigeon's quill. These are in clusters, attached by one end and open at the other. Embedded in the wall of each tube are the spicules above mentioned, projecting both on the outside and on the inside. The inside of the tube is lined with cells bearing cilia which, by their vibration, drive the contained water out of the mouth of the tube; to replace which, water enters through many holes which pierce the wall of the tube. In sponges a little more complicated, the cilia, instead of lining the main tube, are limited to small pouches, or lateral branches of the main tube, extending into the body wall and communicating with the exterior through small pores. In others the cilia are found only in certain enlarged portions of these radiating tubes. This represents the condition in the commercial sponges; certain cavities are lined with cilia and are connected on the one hand with the smaller tubes entering the whole surface of the sponge, and on the other with the large tubes opening at the top. These cilia cause the currents above mentioned. Thus the sponge gets both food and oxygen.

Sponges (including, besides those already mentioned, siliceous sponges, whose spicules are flinty) constitute the branch **Porifera.**

Read *Commercial and Other Sponges*, Hyatt.

Topics for Reports. — Sponge Fisheries. Experiences of Divers. Sources of our Sponges. Fresh-water Sponges.

CHAPTER XVII.

CŒLENTERATA.

THE FRESH-WATER HYDRA.

The fresh-water hydra has a cylindrical **body, varying** in diameter from the size of a fine needle to that of a common pin, and from one fourth to one half an inch in length. It is found in fresh-water ponds and streams, usually attached by one end to submerged stems, leaves, etc., frequently on the under surface of a leaf. Surrounding the free end of the hydra is a circle of threadlike appendages, the **tentacles**, which often are longer than the body itself.

Two species of hydras are found: one green, the other brown or flesh colored, often whitish. Put the leaves and stems to which the hydras are attached into shallow dishes, such as fruit dishes, and keep them in a light but shaded place; watch their behavior when thus kept undisturbed. Cut off a bit of leaf bearing a hydra, and transfer it to a deep watch crystal half full of water. Without the aid of any lens watch the hydra for several minutes. When it is expanded, gently touch it with the tip of a pencil or other blunt object.

Examine a hydra with a hand lens; are all parts colored alike? Place the watch crystal on the stage of a microscope and examine with a one-inch objective. The following points of structure should now be made out: —

1. That the body is a **hollow tube** closed at one end and open at the other. This opening, within the circle of the tentacles, is the **mouth**.

2. That the tentacles are also hollow tubes, closed at their outer ends, but at the inner communicating freely with the body cavity.

3. That the body wall consists of two layers, which are continuous with the corresponding layers of the tentacles. How do these layers differ from each other?

The body is, then, a double-walled sac, and the tentacles are simply extensions of this sac. Watch the movements of the different parts of the body. Can hydras move from place to place? If so, how is this accomplished? Look in the body cavity for foreign matter which has been taken in through the mouth as food. Look also for minute particles obtained by the digestion of such food matter. These particles may often be seen in motion, caused by contractions of the body walls, or by the action of flagella lining the body cavity. Look for knoblike extensions of the side of the body. **Buds** are formed as outgrowths of the body walls with a cavity continuous with the body cavity. Place in a dish by itself with some aquatic plants, a hydra bearing buds, and watch from day to day the development of the bud into the form of the parent. Observe the free circulation of food material from the parent to the bud. Watch the formation of tentacles. Look also for a thinning away of the free end of the bud.

What is the greatest number of buds found on any one specimen? Are buds borne on buds? By means of a pipette transfer a hydra in a large drop of water to a slide. Cut two strips of paper a quarter of an inch long and one sixteenth of an inch wide, and lay one on each side of the drop of water. Carefully place the cover slip on the water, with its edges resting on the papers so as not to crush the specimen.

Examine now with a quarter or one-fifth inch objective. Observe the cells of which the body walls are composed. Note the knotty appearance of the tentacles. In these projections of the tentacles and in the walls of the body are certain distinct oval cells, the **thread cells**. Place a drop of acetic acid on the slide at one edge of the cover slip, and touch the opposite edge of the cover slip with a piece of blotting paper, meanwhile watching the specimen closely. Examine carefully to see the thread

cells which have been discharged as a result of the irritating acid. Small animals coming in contact with the tentacles are paralyzed by means of these thread cells which are suddenly shot out; the tentacles then carry the victim to the mouth, and it is swallowed.

Note the simplicity of the structure of hydra — the absence of any distinct nervous system, and all special organs of circulation and respiration. On the side of a hydra, near the base, may sometimes be seen a conical elevation, the **ovary**, in which the eggs are produced. Also on the side of the body, but near the tentacles, may sometimes be found several elevations, the **spermaries**, in which the sperm cells are produced.

THE SEA ANEMONE.

Look for sea anemones attached to rocks. The beginner in this sort of collecting and observation is usually not prepared for what he sees; he does not usually realize that the name "sea anemone" is exceedingly appropriate, and he is not likely to look for brilliant forms, like sunflowers, asters, and chrysanthemums. Watch them both in their expanded and in their contracted condition. When they are expanded gently touch them. Are they firmly or loosely attached? Do they ever move about? Have they any means of getting food?

In its general form the sea anemone resembles a hydra, having a cylindrical, hollow body attached by one end to some foreign object, and at the free end a mouth surrounded by tentacles. In its internal structure, however, the sea anemone presents some new features. The mouth, instead of opening directly into the body cavity, as in the hydra, opens into an esophagus which hangs like a bag suspended in this cavity; the esophagus has no bottom, but at its lower end communicates freely with the body cavity.

The body wall and esophagus may be represented by a glove finger with its tip cut off and the open end turned back part way into the larger part of the finger.

The cavity of the body is divided into a series of radial compartments by fleshy vertical partitions, the **mesenteries**, which extend inward from the body wall, some reaching the esophagus and being attached to it, others not extending so far inward as the esophagus. Each tentacle communicates with one of these radial compartments, and is to be regarded as a mere extension of part of the body cavity.

Alcoholic specimens should be sliced transversely and longitudinally. In a transverse section of the lower part of the body there will be seen the body wall with a series of partitions extending inward and ending in a free edge. The section across the upper part of the body shows an outer circle, the body wall, an inner circle, the stomach wall, and, connecting the two, the radially arranged partitions, or mesenteries. Like the hydroids, the sea anemone is well provided with thread cells.

Food is taken into the mouth, digested in the stomach, then passed, mixed with sea water, into the body cavity, through which it is made to circulate by the contractions of the body walls. The indigestible portions of the food are expelled from the stomach through the mouth.

STONY CORALS.

(*Coral Proper.*)

In a piece of stony coral, or compound skeleton of a colony of coral polyps (*Galaxea* is a good form to study), make out the following points: —

1. The nature of the material itself; test by putting a very small piece into weak acid, or by touching the specimen with a drop of acid.

2. The **cup**, or **theca**, formed by an individual polyp, often traceable as a long tube. Observe: —

a. The outer wall of the cup.

b. The partitions, or **septa**, extending inward from the wall of the cup.

3. Between the cups, the porous limy secretion, which was

secreted by the common body substance, or **cenosarc**, connecting the individual polyps.

Imagine the sea anemone depositing limy matter in the base of its body wall, forming a cup; fleshy radial ridges rising from the floor and wall of the cup between the mesenteries, and a similar deposit in these ridges; thus it will be seen how the cup is formed by the individual polyp. By the continued growth of the polyp, and the continuation of the limy deposit, the cup becomes an elongated tube. By budding are formed the branches of these tubes, increasing in size and in the number of partitions as they grow.

4. Between the cups, a porous secretion of the same material as that in the cups. This is deposited in the common fleshy base, filling up, in some forms, the spaces between the cups; and when one polyp dies, its cup is covered over and buried out of sight by this secretion of the common base.

5. Make a drawing of a mass of stony coral, showing the general arrangement of the cups, their mode of branching, and the common secretion between them.

6. Draw a cup as seen from its free end. Make also a drawing of a cross section of the same cup toward the smaller end.

In the stony corals the mesenteries are always in pairs, and the fleshy ridges, in which are secreted the septa, arise between them.

The tentacles are generally in multiples of six, and are not fringed. It is of this kind of coral that the reefs are formed.

SEA FEATHER, OR SEA FAN.

In a sea feather, *e.g.*, *Muricea*, note: —

1. An outer barklike layer; with the thumb nail scrape off a little of this layer and pulverize it between the thumb and finger; mix this powder with water and examine under a microscope. A better way to see the spicules is to clean them thoroughly by boiling some of the outer layer in caustic potash. In this layer are holes from which the polyps protruded. In this

form, then, the secretion is wholly in the living matter between the polyps, the barklike layer being composed of the dried flesh in which the spicules lie embedded.

Strip off a piece of the barklike layer and note the grooves on its inner surface. By examining the end of this piece it may be seen that these grooves are caused by a series of tubes running lengthwise near the inner surface of this layer. Find the openings of the tubes where they were broken; these tubes connect the polyps of the colony.

2. The central axis of hornlike substance. Test its flexibility and strength. Observe the grooves on its surface, and the relation between them and the tubes above noted. This horny axis is excreted by the walls of these tubes, and is not penetrated by living matter like the outer layer. In the precious red coral the central axis is formed in the same way, but is calcareous instead of horny, and the outer barklike layer has been removed.

3. Note the mode of branching in a sea fan, comparing the margin with the central portion to see how the meshes are formed. Remove some of the outer layer, and compare with the sea feather. In this group (including sea feathers, sea fans, the precious red coral, etc.) each polyp has eight fringed tentacles; also eight mesenteries, which are never in pairs. An alcoholic specimen, with the polyps expanded, should, if possible, be examined.

Topics for Reports. — Coral Islands and their Formation.

CHAPTER XVIII.

ECHINODERMATA.

STUDY OF A LIVE STARFISH.

STUDENTS who can visit the coast may make profitable study of starfishes in their native haunts. At low tide wade along the shore, looking in tide pools, among rocks and seaweeds, under wharves, etc., for starfishes. Are they found in any special situation? Are they more abundant on one kind of surface than another? Do they seem to prefer sheltered places? Has their color any relation to their surroundings? Are they found in strong light, or do they seem to prefer shaded spots? Do they move? If so, at what rate? Do you find them on the vertical walls of rock? Can they climb? Do they adhere to the surface? If so, how strongly? Try to pull one away from a smooth surface on which you find it. Are they extended flat, or more or less curled up? Are the rays evenly spread out? Do they change the position of the rays to any extent? Are they found singly or in groups? Do they seem to live in colonies? Do you find them eating? If so, what do they eat, and how? Has the situation where you find them in numbers any relation to a food supply? Have they any preference as to the temperature of the water? Are they seriously affected by extreme changes in temperature? At how great depth are they found? Have starfishes any natural enemies? Have they any means of defense? As you reach out to take a starfish, does it seem to be aware of your presence? Is it affected by strong light? By your shadow? By additional heat? By sound? Does it in any way appear to shrink away from you as you take hold of it? Has it any means of stinging or irritating your hand?

Put a live starfish in an aquarium filled with sea water and watch it. Does it move about? Does it crawl up the sides?

How strongly can it hold to the surface it is on? Watch the actions of the tube feet through the glass. Will it climb on a slender support, such as a cane, or large glass tube? Can you learn about its food and mode of eating? Try to get answers to the questions asked above as to the live starfish at home. Do you find any evidences as to the mode of development and growth of starfishes? Do the adults have any care of the young? Do starfishes do any good? Have they economic importance? Do they do any harm? How can their ravages be checked?

EXTERNAL FEATURES OF THE STARFISH.

For this work there is needed: —

1. A set of dried specimens, one for each student; such a set may be used with successive classes and will last for years if carefully handled and kept in a dry place.

2. Alcoholic specimens for dissection.

3. It is desirable to have a set of prepared slides, showing cross sections of a decalcified ray of a young starfish, and a ground-down section of a calcareous plate, etc.

4. An injected starfish and a number of injected rays.

Dried Specimen.

1. Observe, first, the shape of the body as a whole. The central portion is the **disk**, and its radiating extensions are the arms, or **rays**. Note that the rays are bilaterally symmetrical.

2. The mouth is at the center of a thin membrane in the middle of the **oral surface**; the opposite surface is called **aboral**.

3. Cut into one of the rays. Observe that the body cavity is bounded by a leathery wall, in which are embedded hard plates. Compare a piece of a ray of an alcoholic specimen with the dried one.

4. Test the flexibility of the integument of the alcoholic specimen. By picking with forceps, prove that there is soft matter, both on the outside and on the inside of the hard plates.

To show the real nature of the plates and their relation to the integument, proceed as follows: —

a. Handle a starfish which has been decalcified, *i.e.* has had its calcareous matter removed by very weak (two per cent) nitric acid, chromic or other acid. Observe that the body wall is still present, but lacks the hard parts.

b. Examine a microscopic section of a decalcified ray of a young starfish; in such section it should be more clearly seen that the calcareous plates are wholly within the integument.

c. To show still further the relation between the plates and the integument, prepare a thin section of a calcareous plate, as follows: select some pieces of a starfish (left from previous dissection); boil a few of the larger plates in caustic potash in order to remove all the organic matter; wash, and when thoroughly dry, smooth down one side on a fine file; polish on a perfectly clean oilstone; cement the surface of the plate to a glass slide by means of a drop of Canada balsam which has been boiled on the slide, until, on becoming cold, it is with difficulty indented by the thumb nail. Proceed then to plane off, by means of a file, and when quite thin, scrape carefully with a sharp knife, finally smoothing it on an oilstone. The specimen should be examined from time to time under the microscope, in order to ascertain when the proper degree of thinness has been reached. Dissolve the balsam by means of turpentine, or better, if properly managed, melt the balsam over a lamp, and carefully push the section into a watch crystal containing turpentine; when thoroughly freed from balsam, carefully brush it with a camel's-hair brush, and mount in Canada balsam in the ordinary manner.

5. Observe the arrangement of the plates and spines in different regions of the body wall. Along the middle of the oral surface of each ray may be seen the shriveled remains of the tube feet, or **ambulacra**. The region in which they lie is the **ambulacral area**. The plates along this tract are the **ambulacral plates**. One row of plates on each side of these ambulacral

plates are known as the **interambulacral plates.** Examine these closely for comparison with the sea urchin.

6. The wartlike elevation on the aboral surface is the **madreporic body.** Note that it is situated opposite one of the **interradial angles.** Examine it with a lens.

7. Make drawings of the oral and aboral surfaces of the starfish.

ALCOHOLIC SPECIMEN.

1. Briefly review the points noticed in examining the dried specimen. Bend the rays; their flexibility is now much less than in life.

2. Compare the spines of different areas as to their shape, size, and degree of mobility.

3. Between the spines are soft, tapering projections, the **aboral tentacles.**

4. Observe a circle of projections surrounding the spines; delicately pinch them with the forceps to determine their consistence; remove some of these bodies to strong alcohol; mount temporarily in turpentine on a slide, cover, and examine with a low power. There should be distinguished a short stalk bearing a pair of pinchers; these bodies are the **pedicellariæ.** In the live starfish these pinchers may be seen continually snapping; they are supposed to serve in removing foreign matter from the body.

5. The soft, cylindrical projections along the median tract of the oral surface of each ray are the **ambulacra** or **tube feet.** Remove one of them and examine it with care. Note the arrangement of the series.

6. Press apart the tube feet and find running along the median line of the ambulacral groove, a yellowish or whitish ridge, the **nerve** of the ray. Trace it to the soft membrane bordering the mouth, the **peristome**, and find the **nerve ring** around the mouth.

7. Trace the nerves also to their outer ends and find a reddish or yellowish elevation, the **eye-spot**, borne at the base of a median terminal **tentacle,** resembling a tube foot.

8. The eye-spot is borne on a distinct, but minute, plate. Compare young and old specimens to see that whatever the size, this single ocular plate with its eye-spot is always at the end of the ray. Count the ambulacral plates in a short and in a long ray. Where do the new plates develop?

DISSECTION OF THE STARFISH (IN WATER).

1. The ray opposite the madreporic body is the **anterior ray.** Cut into its aboral wall near the outer end, and from this point cut along the upper part of each side of the ray, an inch or two toward the disk; raise the flap thus freed, and, avoiding internal organs, continue the cut on each side to the disk.

2. Attached to the aboral wall find a pair of elongated, branched bodies, the digestive glands, or **ceca.** Note how each cecum is held in place by the thin **mesentery.**

3. Along the middle line of the aboral wall, inside, is a yellowish streak, the **extensor muscle** of the ray; with forceps prove its general structure.

4. Along each side of the ridge in the floor of the ray, observe rows of thin-walled sacs, sometimes distended, but more often collapsed in alcoholic specimens. These are the **ampullæ,** or **ambulacral vesicles.** Watch the ampullæ while pressing on the tube feet, and *vice versa.* If a specimen injected with coloring matter be at hand, it should now be examined.

5. Near the base of the ray find, on each side, an elongated body resembling a bunch of grapes, and of a lighter color than the ceca; these are the ovaries and spermaries, and are very much alike in appearance in the two sexes, and only distinguishable by color (the spermaries being lighter colored), or by microscopic examination in the living specimens. Find the point of attachment of one of them. The openings in the interradial angle are not very evident.

6. Cut along the sides of the two rays lying on the right and left of the anterior ray, connect the cuts at the interradial angles, and turn back the cover of the three rays and disk. Within the

disk is the large, thin-walled stomach. Examine this organ carefully. Pass a blunt probe into the mouth and explore its interior.

7. Observe the large lobes of the stomach extending a short distance into the rays; lift one of these lobes and trace the thin **retractor muscles** of the stomach to the sides of the ridge in the ray.

In the live starfish the stomach is often found protruded and surrounding a mussel or an oyster; after digesting and absorbing its soft parts the stomach is retracted.

8. Turning to the ceca of the anterior ray, trace them toward the stomach; find the union of their tubes and the entrance of their common duct into the stomach. Observe the place where this tube enters the stomach, in reference to the corresponding lobe of the latter.

Carefully cut the mesentery along the aboral wall and wholly free the ceca of this ray from all attachment above. Note that the mesentery is double.

9. Hold the starfish inverted and pour water through the mouth into the stomach to show its shape.

10. In the other two rays which have been opened, cut across the common ducts of the ceca close to the stomach, and leave them attached to the aboral walls.

11. Find the extremely short intestine connecting the stomach with the upper wall of the disk, near the junction of the extensor muscles of the rays. Find, also, some small branched appendages of the intestine. The anal opening is minute.

12. Sever the intestine close to the aboral wall, cut across the disk close to the madreporic body, and remove entirely the roof of the disk and the three rays.

Make a drawing of the organs now exposed, showing the ceca in one ray, the reproductive bodies in another, and the ampullæ in the third.

13. Thoroughly examine the stomach, and remove it after cutting across the short esophagus.

14. The S-shaped **stone canal** may now be seen passing downward from beneath the madreporic body.

15. Traced to its lower end, the stone canal may be found to enter a membranous hollow ring, whose outer border rests against the inner surface of the hard parts surrounding the mouth ; this tube is the **circumoral water ring.** Connected with its inner surface, find several pairs of pouches, which in the contracted state are mere buttonlike projections. How many of these are there, and are they all in pairs ?

Observe also the pouches, like ampullæ, connected with the upper part of the hard ring around the mouth. Press on the water ring at the level of the peristome, and watch the effect of this action on these last-named pouches or vesicles. Is there any connection between them and the water ring?

16. Inclosing the stone canal is a thin membrane, the **pericardium.** Carefully tear it away. Alongside the stone canal is a soft tube, sometimes called the "**heart,**" but whose function is doubtful.

17. Cut across the middle of a ray in two places, about an inch apart, and make a careful study of the part included between the cuts. Remove the hepatic ceca, observing again how they are suspended by the mesenteries. Cut into the aboral wall in the middle line and spread open the ring. Observe the depressions in its inner surface ; in the bottoms of these depressions find small holes. What is the relation between these holes and the nearest structures seen on the outside ?

18. Slowly peel away the thin membrane which lines the interior of the ray, noting especially the connection between this membrane and the depressions above noticed. Also watch closely the aboral tentacles while tearing away this lining membrane.

19. Turn now to the outside of the ray and gently scrape the surface. A thin layer here may also be easily removed. Thoroughly clean a small area, noting that the aboral tentacles come away with this layer.

There will now remain a tough white layer in which are embedded the calcareous plates which constitute the skeleton.

Bend this membrane to see the relations of the calcareous plates to the membrane and to each other.

20. By picking with the forceps prove that the membrane is continuous over both the inner and outer surfaces of the plates, as well as between them. This is an important point, as the calcareous plates are developed in and by the membrane.

Part of the membrane, if not all, has the power of contracting, by means of which motion is effected. Note the perforations in the membrane in its thinner portions between the plates where the aboral tentacles passed out.

21. Reviewing what was noticed in the examination of the inner and outer membranes, it will be evident that the aboral tentacles are tubular extensions of the body formed by the protrusion of the inner membrane through the middle membrane, these tubes being covered by the outer membrane.

22. Turn now to the tube feet and their ampullæ and make out their relations to each other and to the adjacent parts of the skeleton. The calcareous plates which form the sides of the ambulacral groove are the ambulacral plates.

23. Pick away a few of the ampullæ and then the corresponding tube feet, comparing the arrangement of the two. In this way clean the ambulacral plates and examine them carefully.

24. Alternately press the ambulacral plates of the two sides together and separate them to see the range of motion allowed by the joint. Observe the muscles connecting the ambulacral plates of the opposite sides, just inside of the nerve.

25. In the angle formed by the ambulacral plates, find the cut-off end of the **water tube** of the ray. Insert in the end of this the point of a drawn-out glass tube, and inflate. When the ampullæ are distended, press on them with the finger and note the effect on the tube feet; with a lens examine the distended ampullæ. In fresh specimens the ampullæ may be injected with a colored liquid or with gelatine to be kept as permanent preparations. In such preparations and in a microscopic section

of a properly prepared ray, it may be seen that the water tube of the ray sends off side branches to the tube feet, and also that the cavities of the tube feet and ampullæ are continuous. By the contraction of the ampullæ the tube feet are extended, and by the muscles in their walls they are moved from side to side and applied to the surfaces on which the starfish rests. The end is fixed by means of the suckerlike disk at the tip of the foot to some foreign object; then, by the contraction of the tube feet, the starfish pulls its body along.

The water finds its way through the madreporic body into the stone canal, thence to the water ring around the mouth, and from this to the radial canals. The water thus taken in probably serves for respiration as well as for locomotion.

26. Make a drawing of a cross section of a ray, showing as many as possible of the above-noted points of structure. A slide with a series of very small starfishes shows well how the rays are formed as outgrowths of the disk.

Read *Seaside Studies in Natural History*, Agassiz.

Topics for Reports. — Starfishes and the Oyster Industry.

THE SEA URCHIN.

Study of a Live Sea Urchin.

At low tide search the tide pools for sea urchins. For collection and study, follow the directions given for the study of the live starfish. Keep sea urchins in a salt-water aquarium and study their habits. Turn a sea urchin upside down in the aquarium. Can it turn back? How does it accomplish this, and how long does it take to right itself?

The requisites for this work are, cleaned skeletons, or tests, alcoholic specimens, microscopic sections, etc., as in the case of the starfish.

The Cleaned Test.

1. Observe the radial distribution of the parts around an axis, at one pole of which, the *oral pole*, is a large opening. At the

opposite pole, the *aboral pole*, is a circular area composed of several small plates, near the center of which is the anal opening.

2. Note that the test is composed of distinct pieces or **plates.** Put one of the plates into a little dilute acid and note what occurs.

3. To make out the real nature of the skeleton, proceed thus:—

a. Handle an entire decalcified specimen, *i.e.* one from which the calcareous matter has been removed by chromic or other acid. Observe that the body walls and spines are still present.

b. Examine a microscopic section of the decalcified body wall to see that there was soft living matter, both on the outside and on the inside of the calcareous plates.

c. Grind down and mount a thin section of a plate, as in the case of the starfish, and see that not only is the plate wholly inclosed in the body wall, but that it forms a network whose meshes were penetrated by the soft living substance of that body wall. It should now be clear that the plates were formed by the deposition of calcareous matter within the living tissues of the body wall. The joints, or sutures, between the plates are formed by the absence of the deposit of calcareous matter.

4. Returning to the entire test, study the arrangement of the plates, their variations in shape, size, etc. Into how many similar areas may the surface of the test be divided? To make out these points, and the shapes of the plates, pull apart a piece of a dried test that was left over from previous dissection.

5. At the aboral pole, observe a small, distinctly marked-off area, including numerous small plates. This is the **anal area,** and the plates are the **anal plates.** Unlike the other plates, these, in the living sea urchin, are movable. They surround the **anus.**

6. Surrounding the anal area are the five large **genital plates,** each having a **genital opening** near its outer angle.

7. With a lens examine the largest of the genital plates; its perforated portion serves as a **madreporic body.**

8. Radiating from the apex of each genital plate is the zigzag **interradial suture**. How many kinds of plates are found within the area included by two adjacent interradial sutures? The perforated plates are the **ambulacral plates,** and the unperforated, the **interambulacral plates**. Compare these two sets of plates with the corresponding parts of a starfish.

9. The ambulacral plates form the **ambulacral areas**. Trace each of the ambulacral areas to its aboral end, and find at its apex a small plate wedged in between two adjacent genital plates. These smaller ones are the **ocular plates**. Note the small opening from which projects an unpaired tentacle, the end of the radial water tube.

10. Carefully compare the hard parts of the starfish and sea urchin. Wherein are they alike, and wherein do they differ? What changes in growth would be necessary to convert one of these forms into the other? What part of a starfish is homologous with the anal area of a sea urchin?

11. Make careful drawings of the oral surface, of the aboral surface, and of the side of the test.

Alcoholic Specimen.

For the sake of review and comparison, it is well to have the cleaned test before you during this study.

1. Observe the soft membrane, the **peristome**, on the **oral surface** and the **teeth** projecting from the **mouth**.

2. At the aboral pole look for the anus and genital plates.

3. Examine one of the largest spines; move it about to see its range of motion. Remove it and make out how it is articulated to the test. The fleshy tube ensheathing the base is muscular tissue, by the shortening of which the spine is moved. Clean the spine and make a drawing of it.

4. Note any variations in the size and shape of the spines in various regions.

5. Study carefully the arrangement of the spines, using the cleaned test for comparison.

6. Between the spines in certain areas find soft tubular projections, the **tube feet**, or ambulacra. In life they may be extended a considerable distance beyond the spines, being used for locomotion, as in the starfish; carefully examine the tips of the tube feet to find what is therein contained.

7. Find also among the spines and on the peristome, slender, flexible stalks, bearing three-pronged pinchers. In life these pinchers keep opening and shutting.

8. Pick away the spines and other projections preparatory to dissection.

Dissection of the Sea Urchin.

After removing the spines, cut, or better, saw with the blade of a metal saw, through the equator of the test; place under water and carefully raise the aboral portion at one side.

1. Press on the tips of the teeth to show their connection with the complicated apparatus known as the **lantern**; now open the test till the two halves are side by side and complete the dissection under water.

2. Arising from the middle of the inner surface of the lantern find the brown **esophagus**. Trace this as it passes in festoons about the body walls, widening to become the stomach. Trace the intestine to the anus, describing carefully its course.

3. Pick away the digestive tube from the oral half of the test. Note the five double rows of ampullæ; between each of these double rows runs the radial water tube, and between the water tube and the test is the radial nerve.

4. In the aboral half, note the ovaries and spermaries in the loops of the intestine. Trace their ducts to the genital pores.

5. After cleaning away the intestine, ovaries, and spermaries, trace the ampullæ as they converge to the ocular plate. Compare the inside and outside of the test to see if the ampullæ are really opposite the ambulacral pores noticed in the dry test.

6. Study the lantern, make out how it is supported, and how its various parts are moved, and how they are used.

Place in water the pieces of test left after dissection and macerate till the spines are readily detached. Then clean and keep them for the next class. They will be useful for pulling to pieces to make out the structure of the test.

Topics for Reports. — Boring Sea Urchins.

CHAPTER XIX.

TROCHELMINTHES.

THE WHEEL ANIMALCULE (ROTIFER).

ROTIFERS are often found in the water of an aquarium where clams and crayfish have been kept; pick out clusters of plant growth, found in the rubbish and sediment in the aquarium, or on the shells of clams; with a lens look at the walls of the aquarium for small, white, wormlike forms.

The body of the wheel animalcule is tapering, ending in a two-forked **foot.** At the larger end, when expanded, are two circular **disks**, fringed with cilia; the disks are retractile, as in Vorticella. Between the disks is the mouth; this opens into the **pharynx,** lined with teeth; back of the pharynx are the stomach and intestine.

Rotifers are classed with the worms; though small, the presence of a distinct digestive tube, a distinct nervous system, and organs of sight and hearing, show the Rotifer to be much more highly developed than the protozoans.

Rotifers have been dried and kept for years, and yet when put into water they revived.

Study carefully: —

1. The mode of locomotion.
2. The action of the disks and cilia.
3. The motions of the pharynx.
4. The contraction and expansion of the body as a whole.

Make drawings showing the body both in the expanded and in the contracted state.

Read the "General Characters of Rotifers" in Packard's *Zoölogy;* "Rotifera" in Claus and Sedgwick's *Text-book of Zoölogy;* "Trochelminthes" in Parker and Haswell's *Text-book of Zoölogy.*

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Teeth

Dog Incisors $\frac{3}{3}$ - $\frac{3}{3}$ sharp chisel-like
Canines $\frac{1}{1}$ - $\frac{1}{1}$ curved backward,
molars $\frac{6}{7}$ - $\frac{6}{7}$ chewing

Sheep. Incisors $\frac{0}{4}$ .. $\frac{0}{4}$ cuts the grass
Canine - - —
molars $\frac{6}{6}$ $\frac{6}{6}$

Cat Incisors $\frac{3}{3}$ - - $\frac{3}{3}$ biting off

Canine ~~none~~ $\frac{1}{1}$ -- $\frac{1}{1}$ long curved ba

molars $\frac{4}{3}$ - - - $\frac{4}{3}$ cylindrical, pa

crushing + gu

jagged + ire

Sheep